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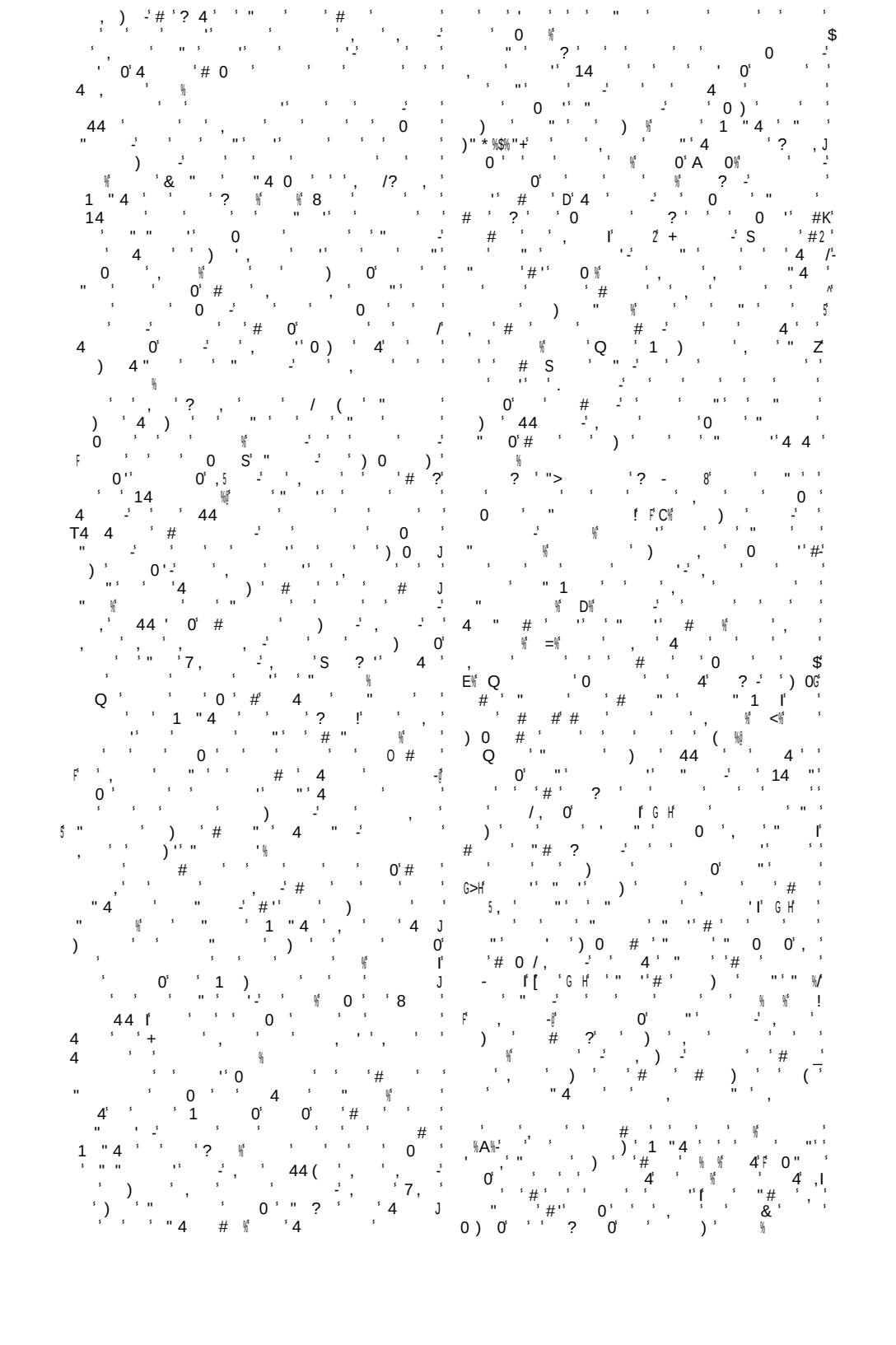

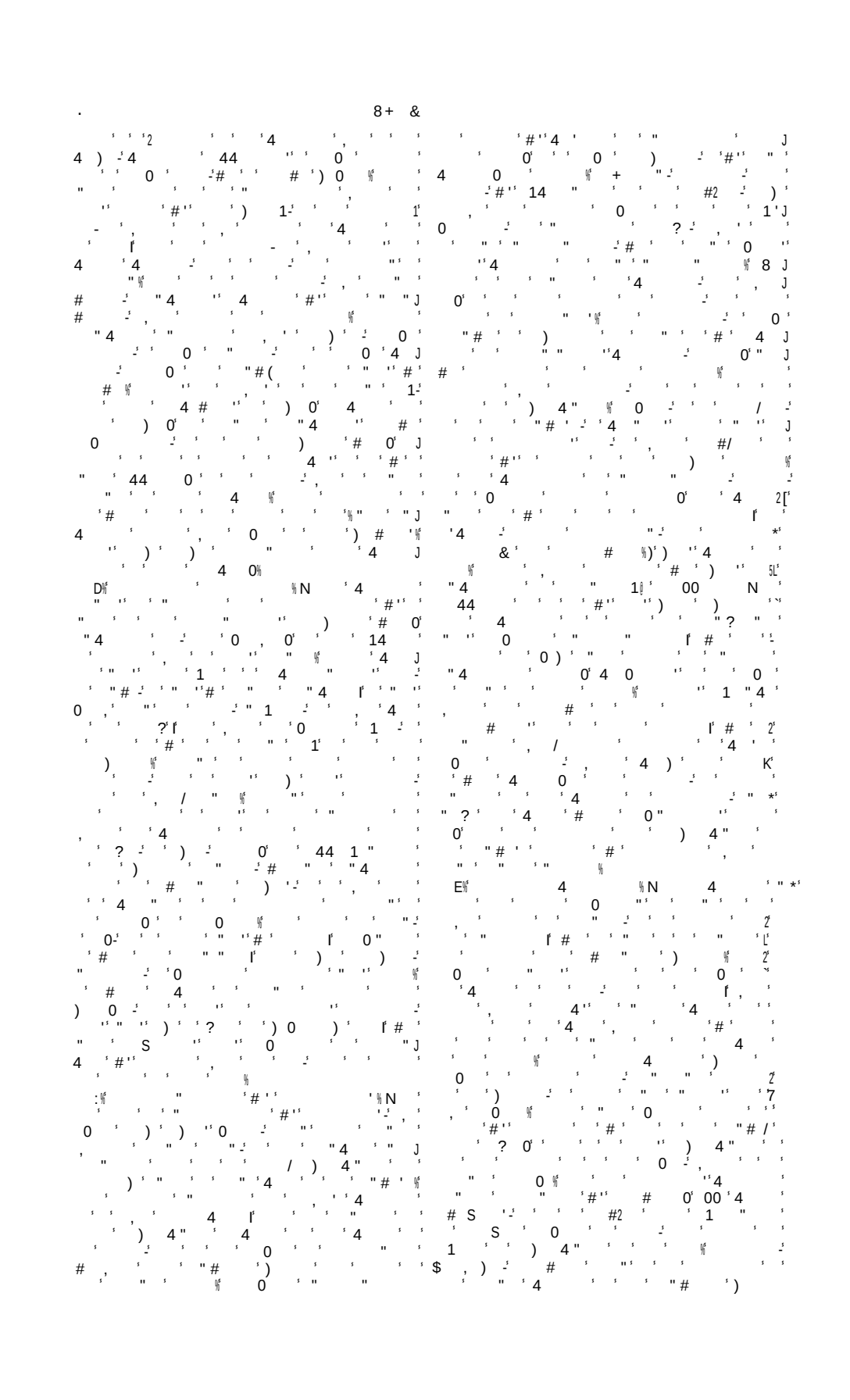

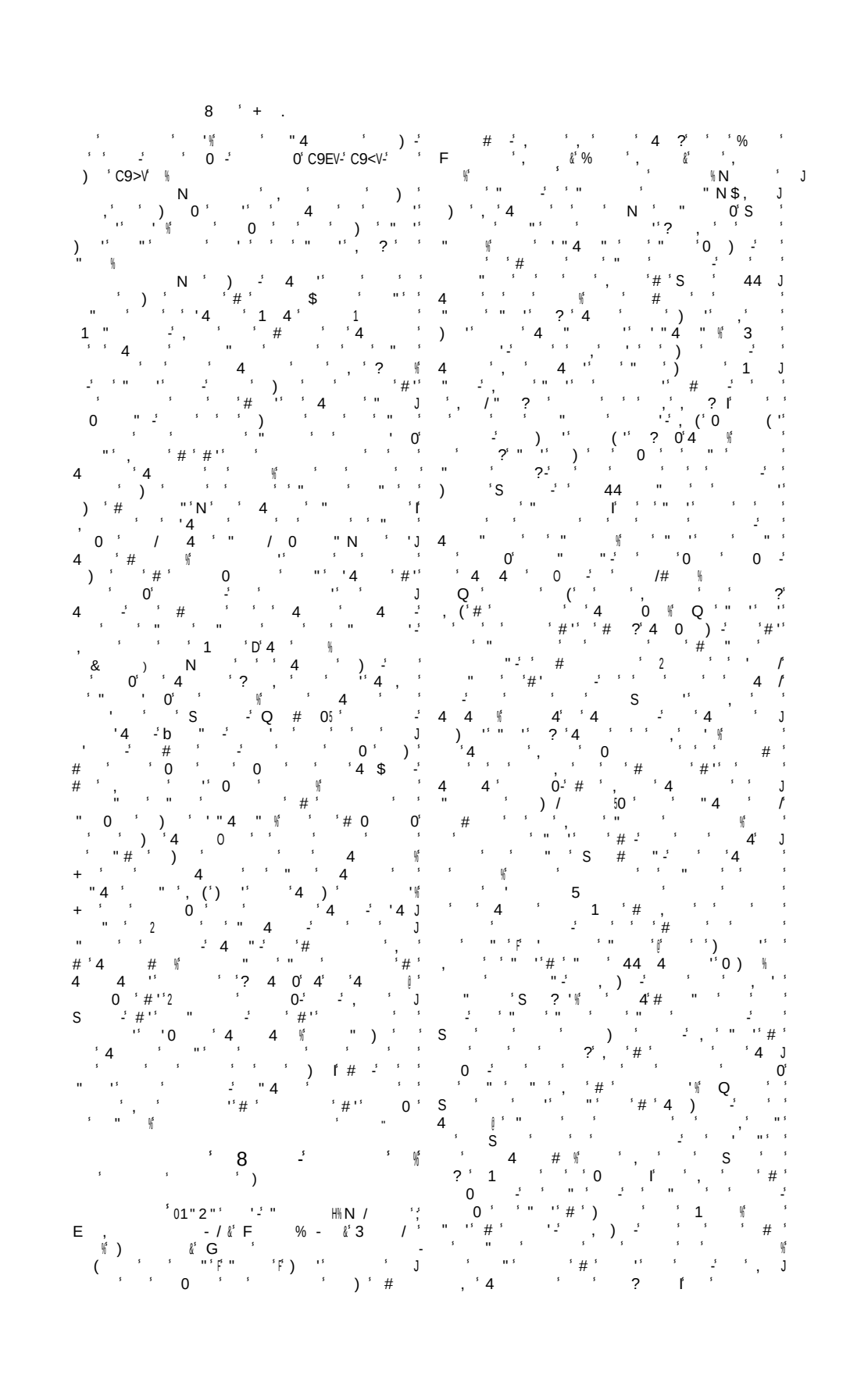

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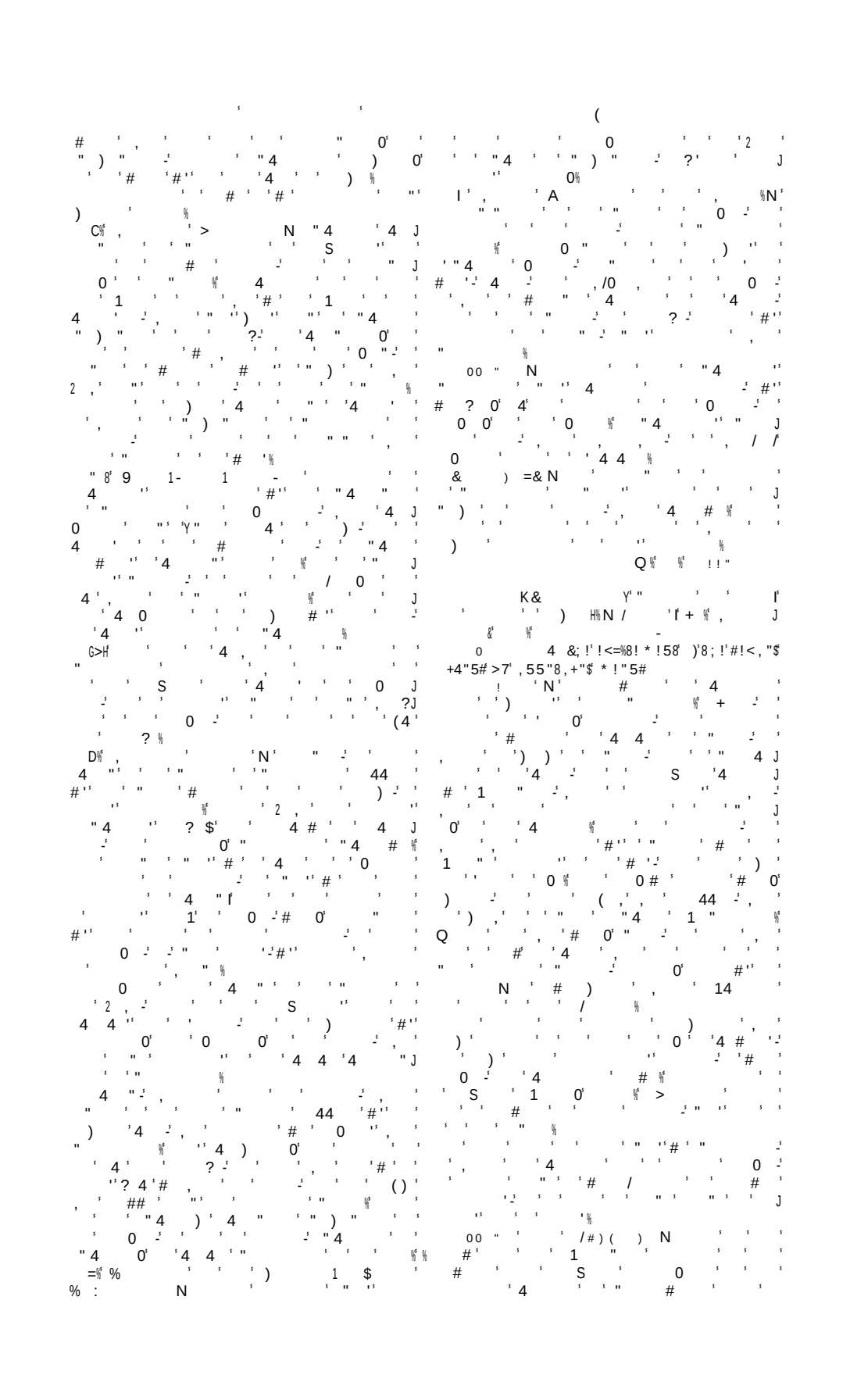

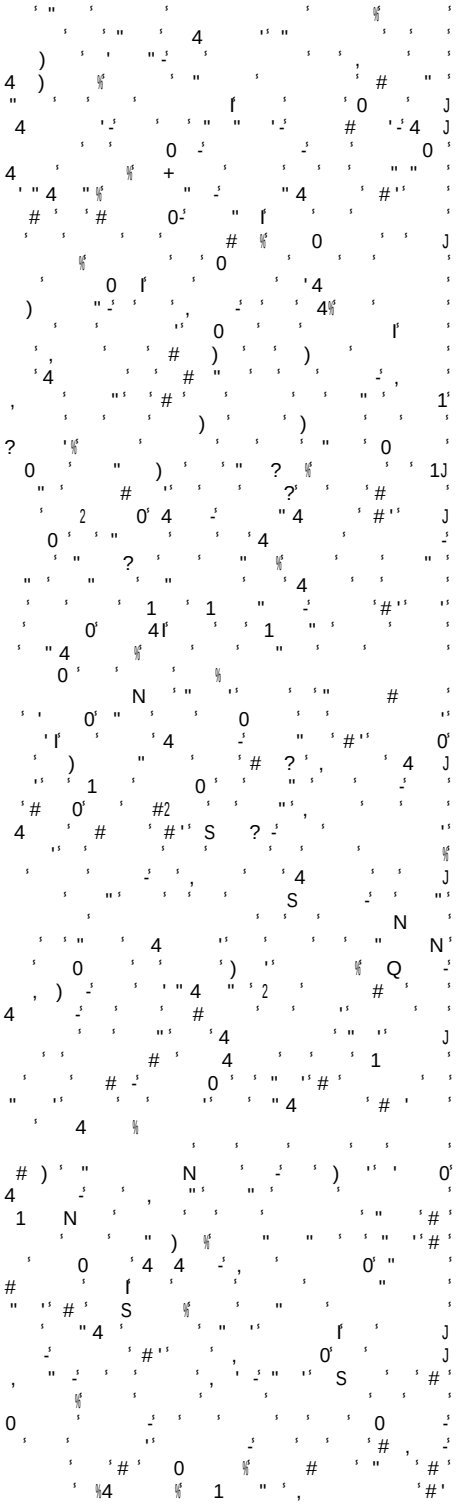

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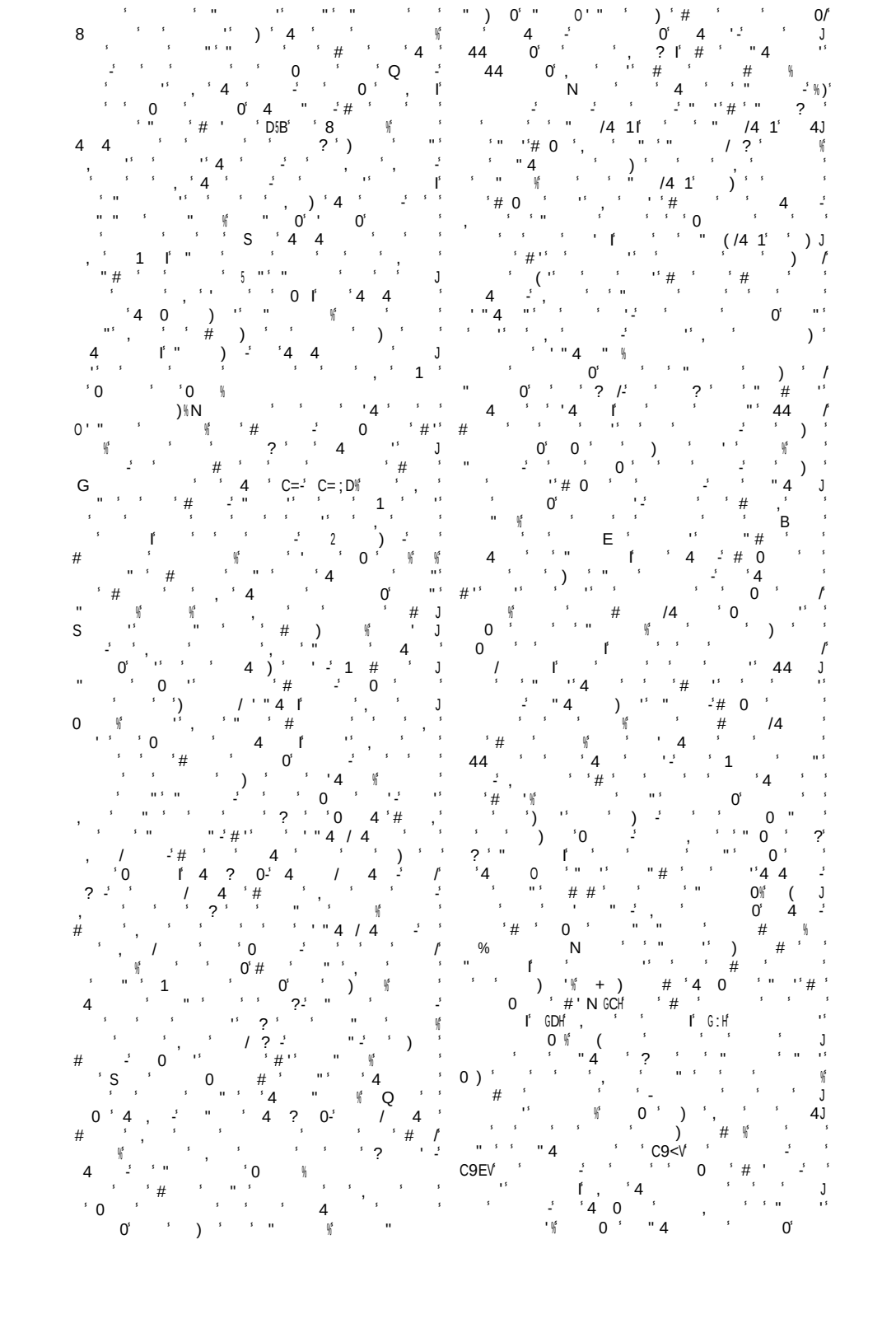

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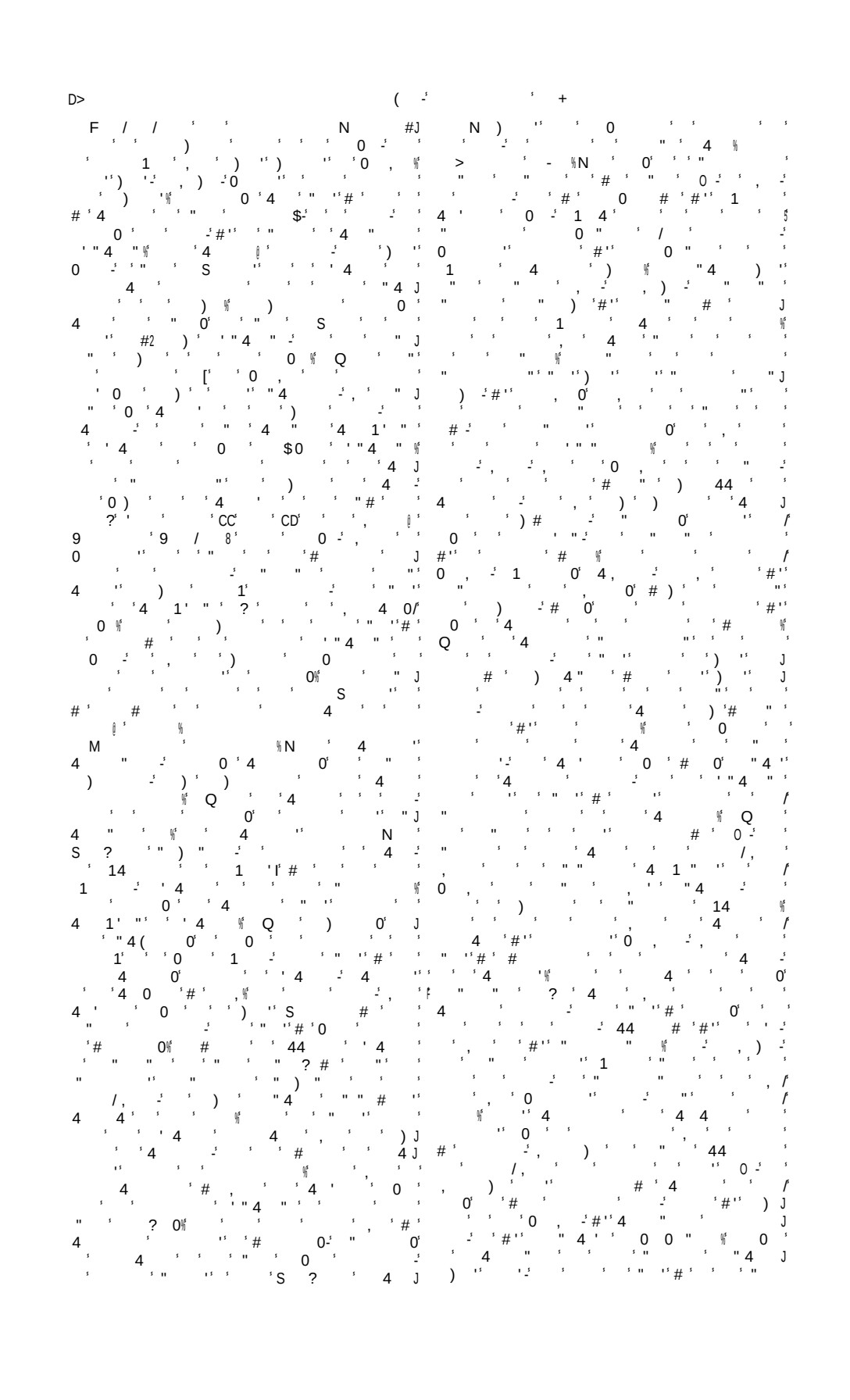

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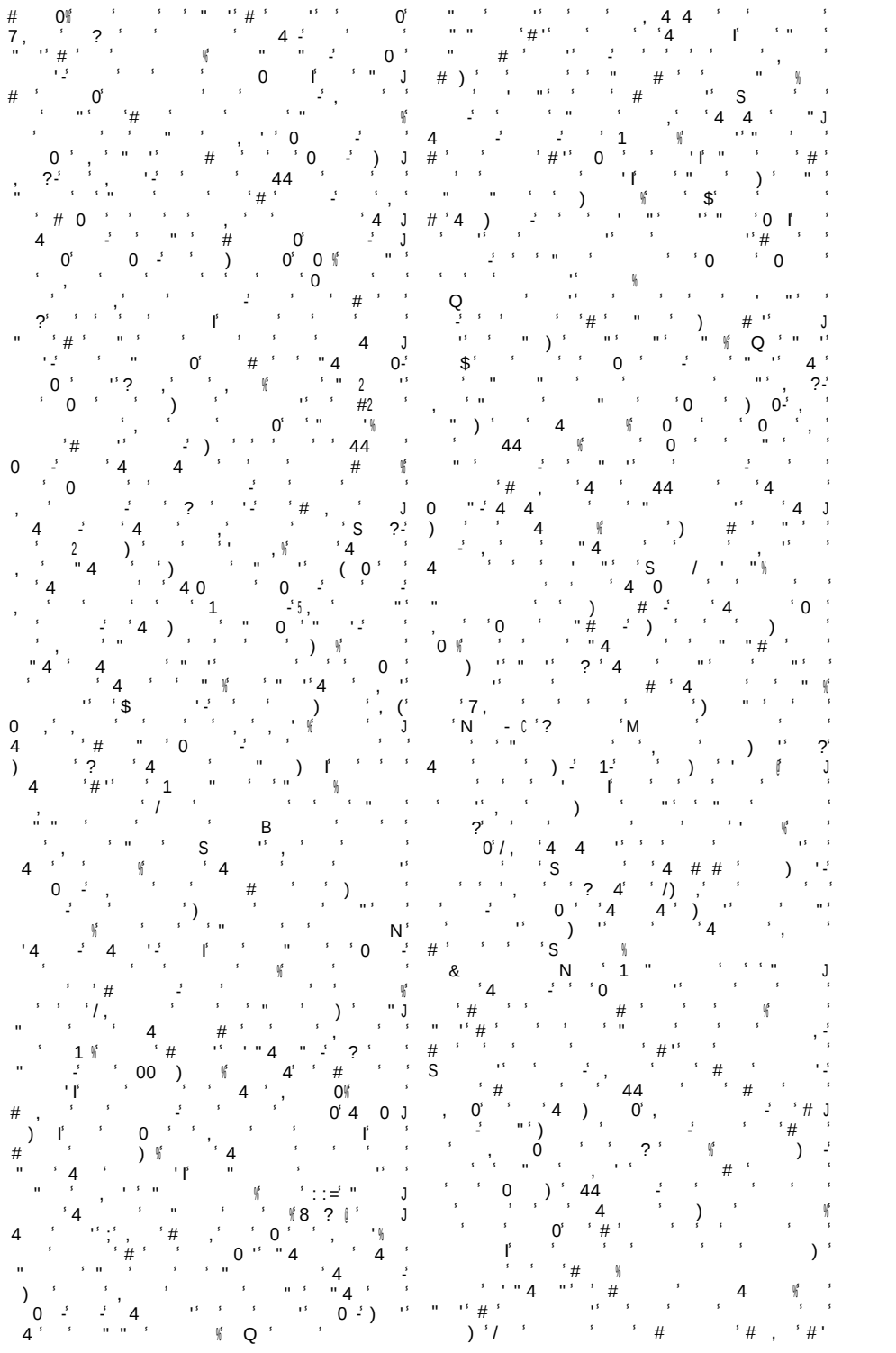

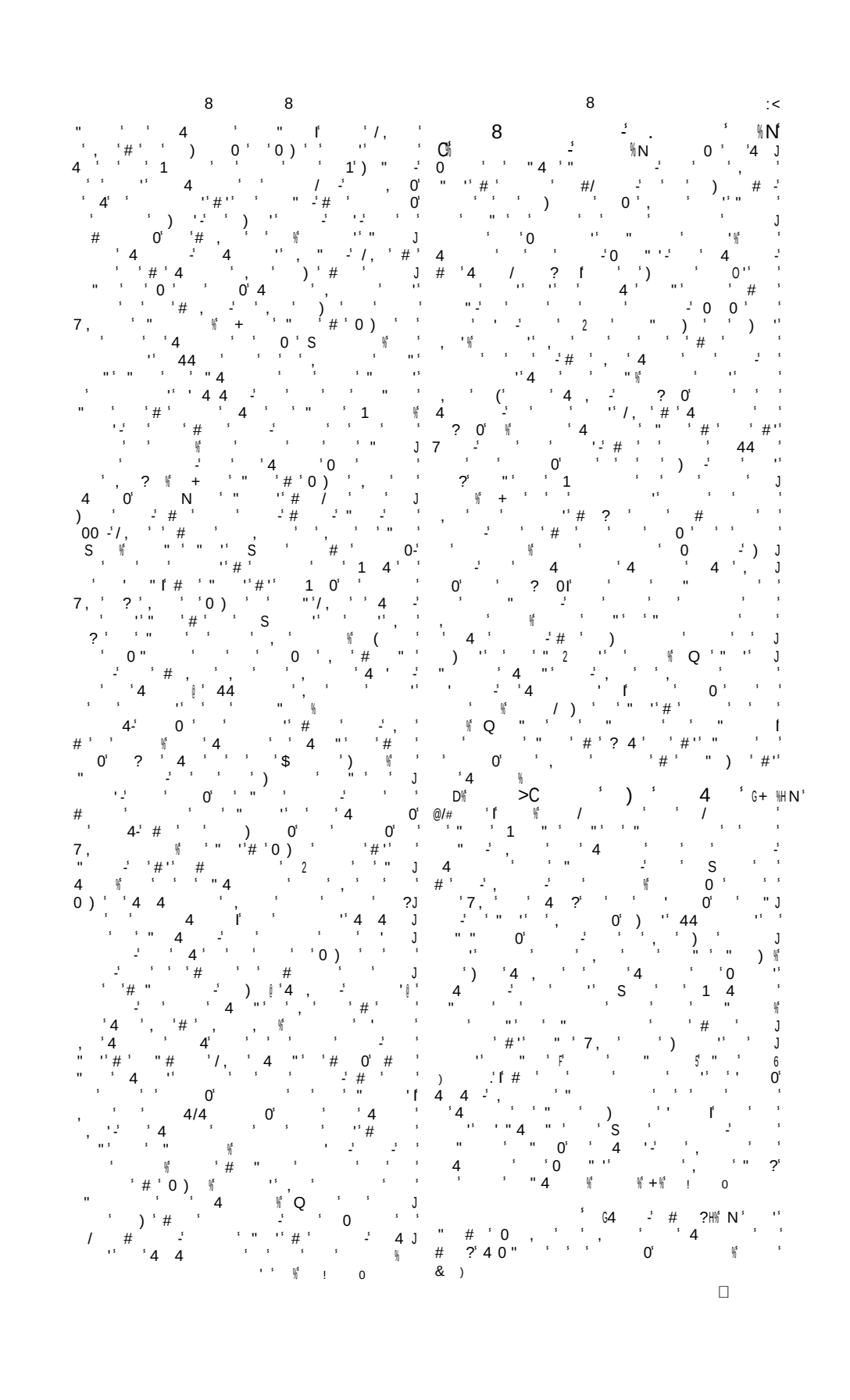

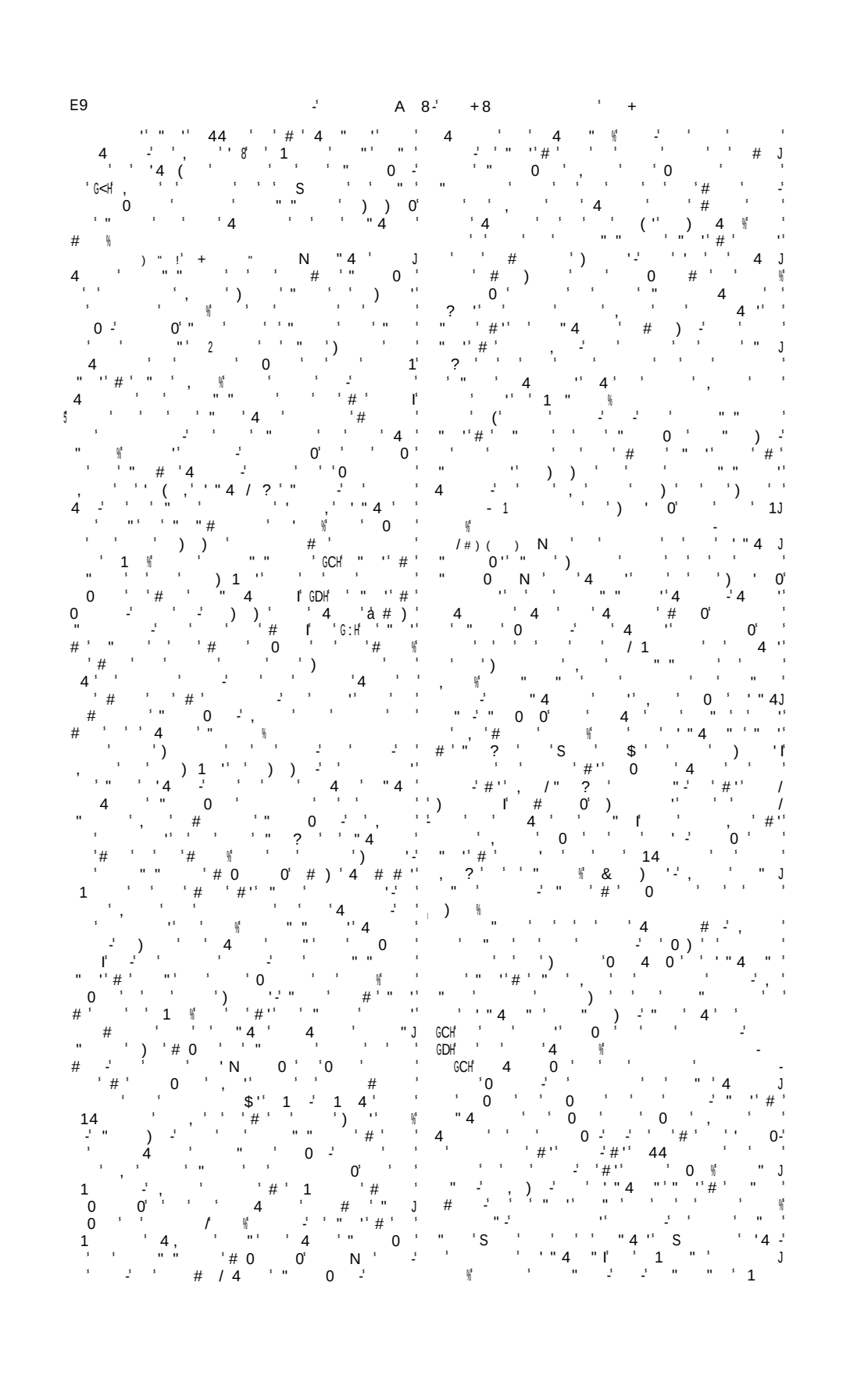

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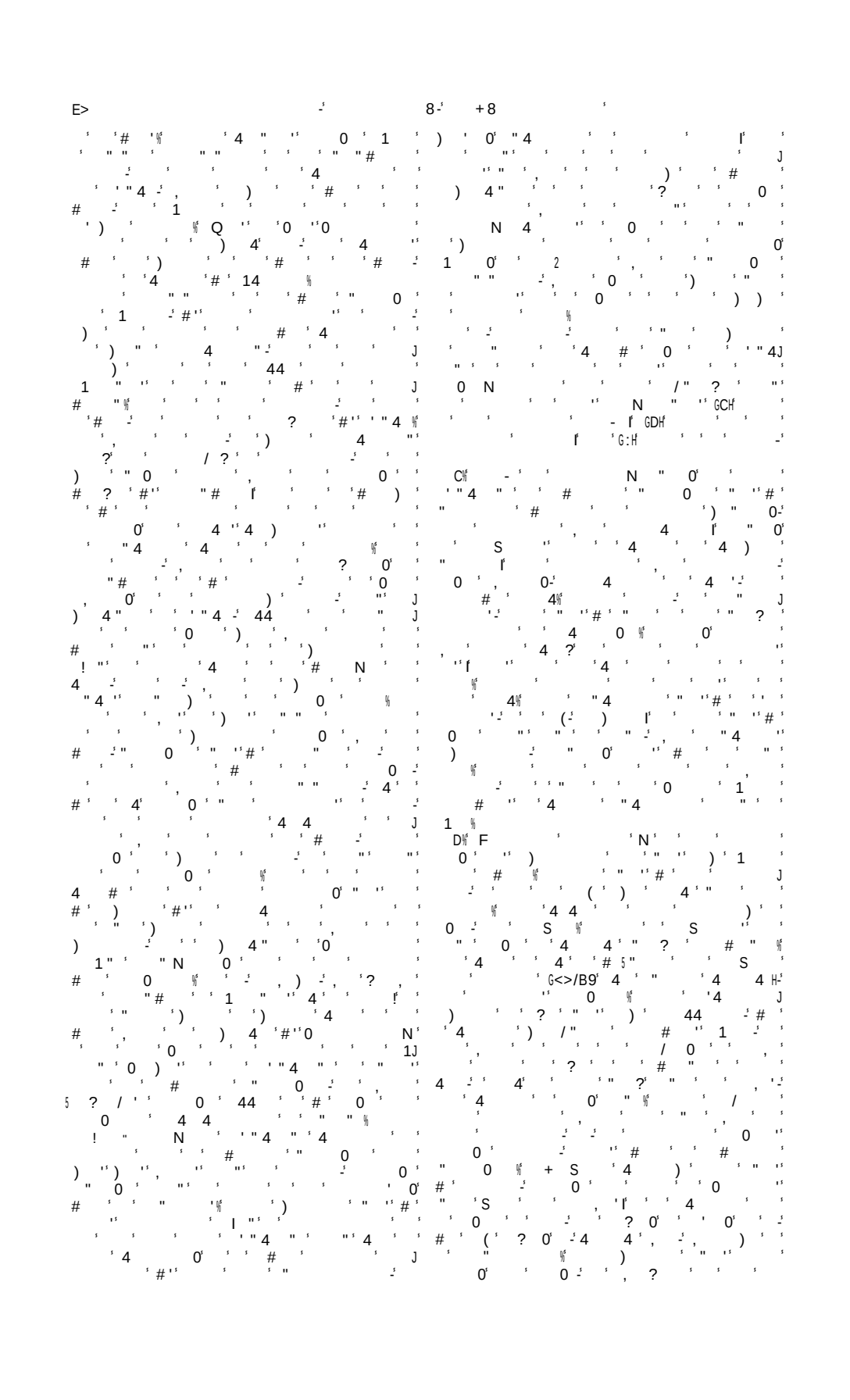

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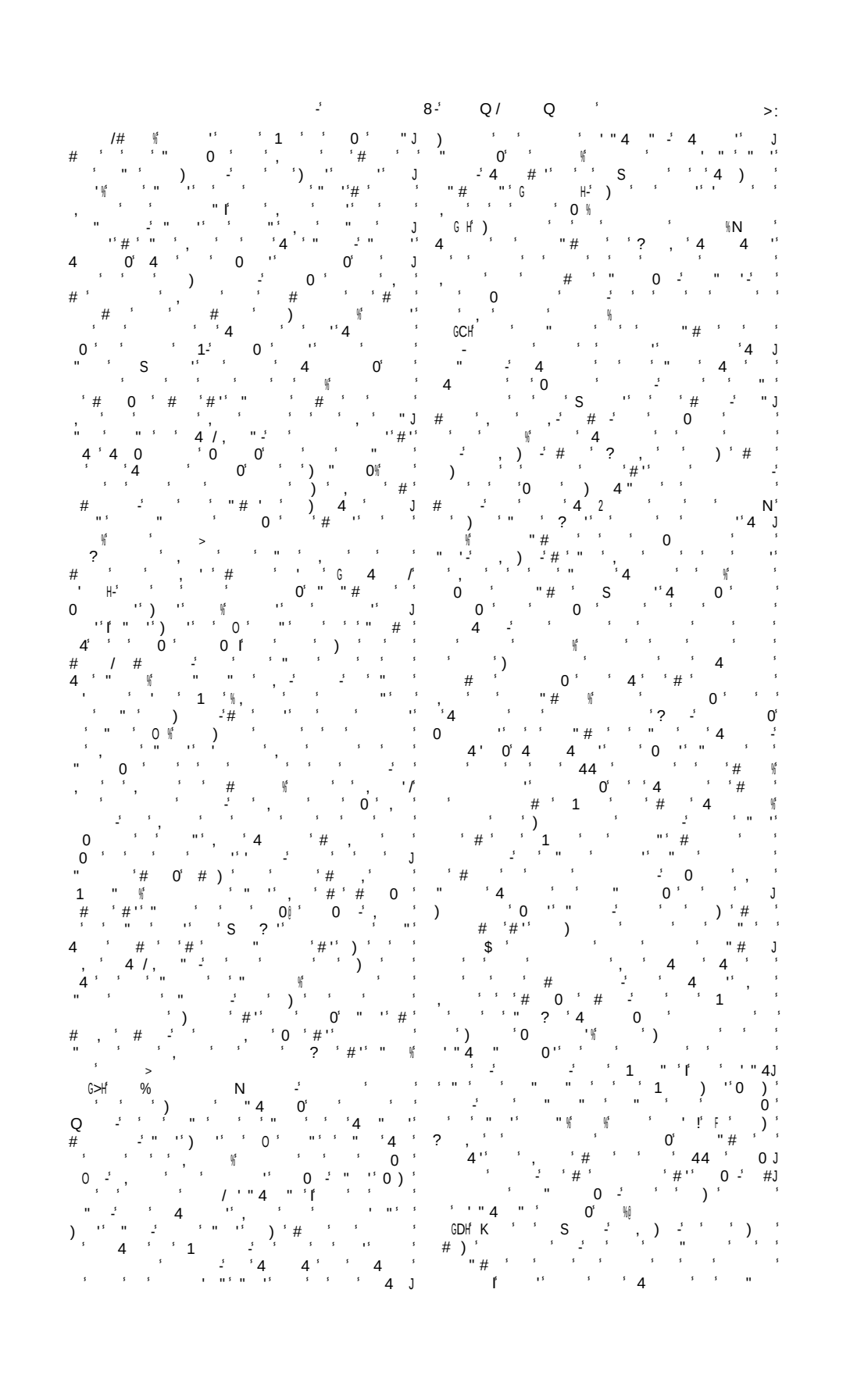

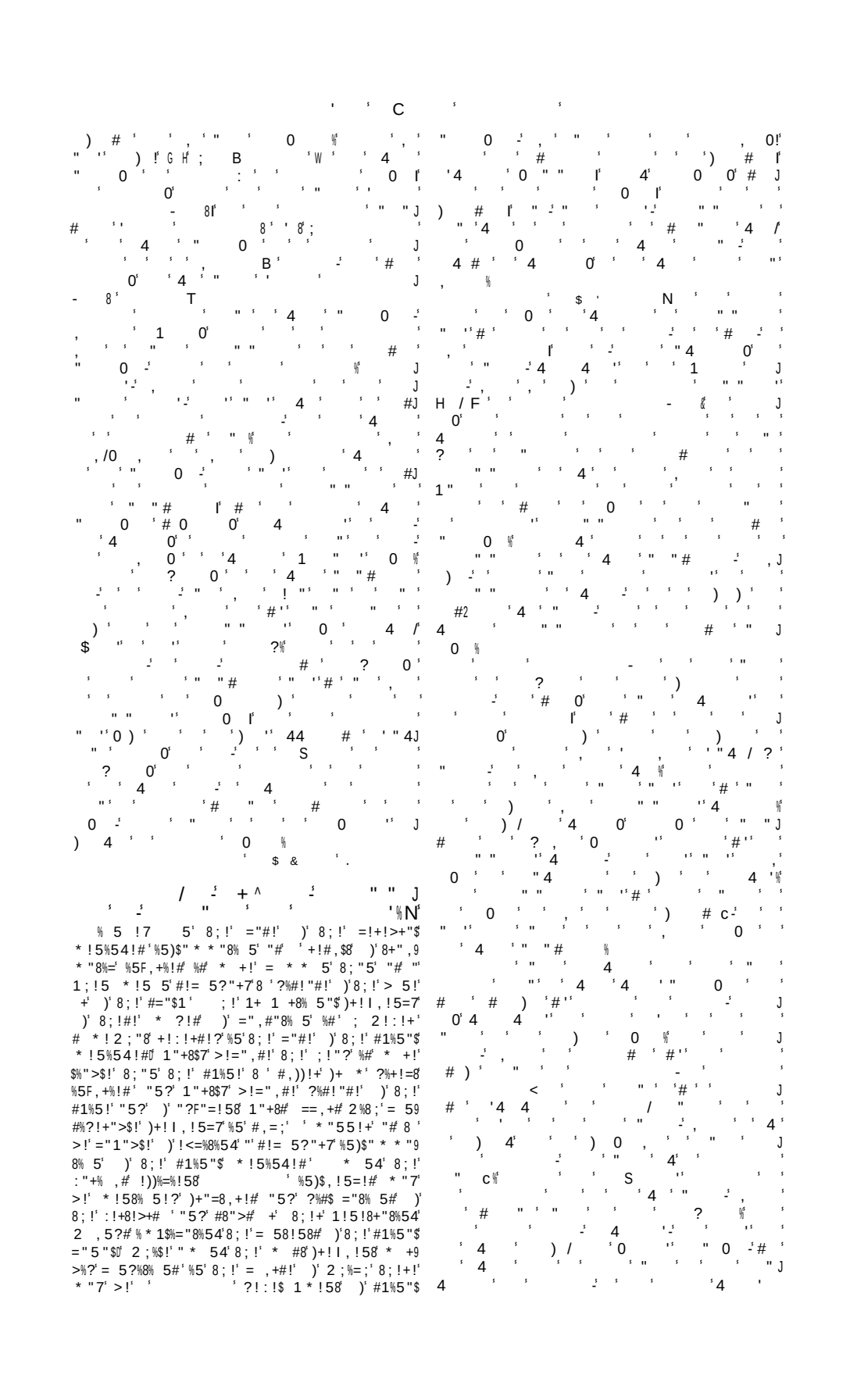

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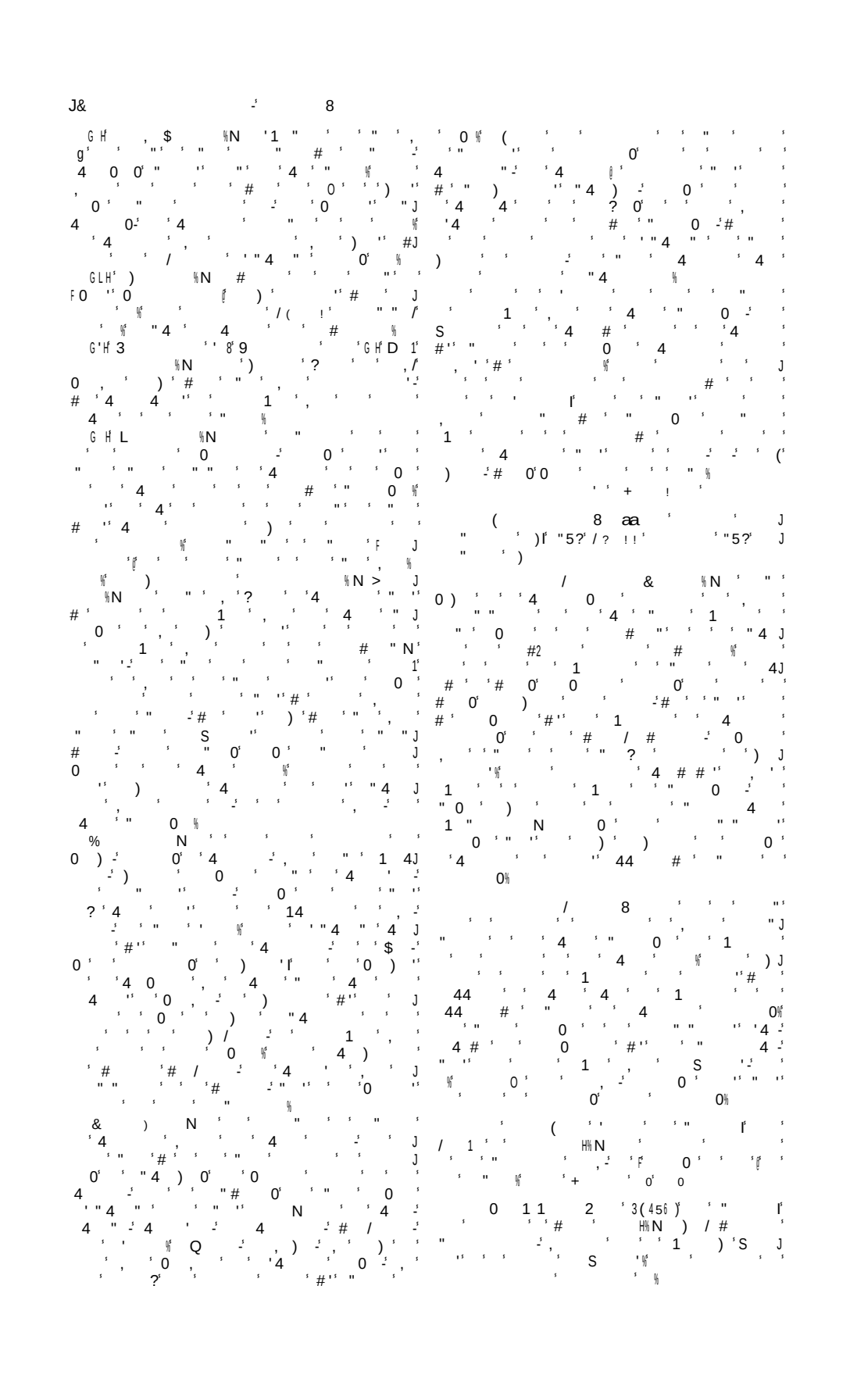

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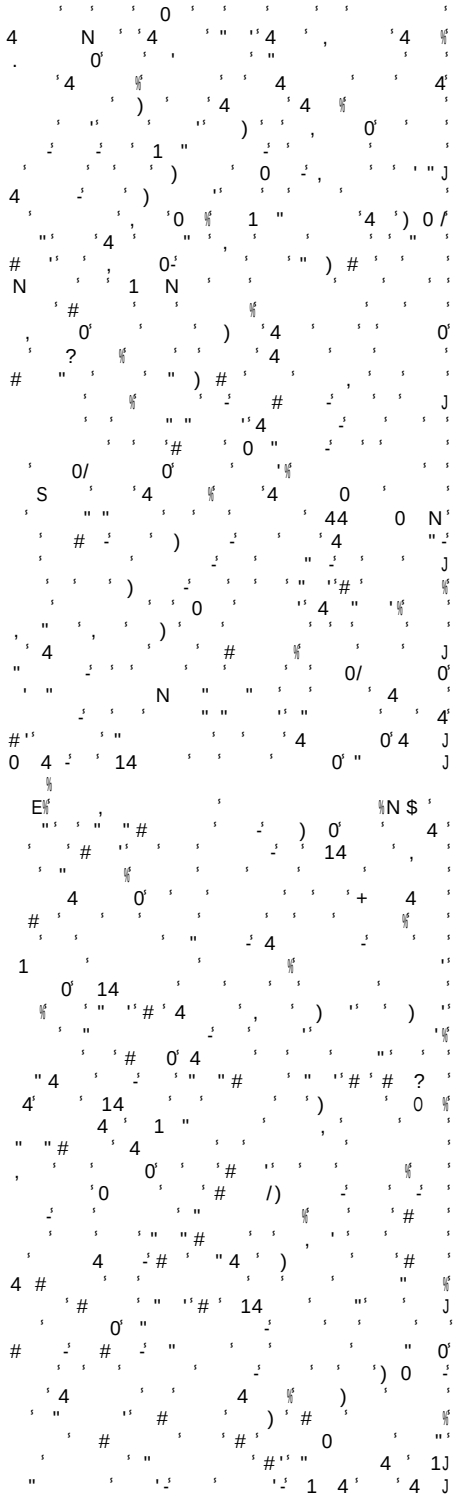

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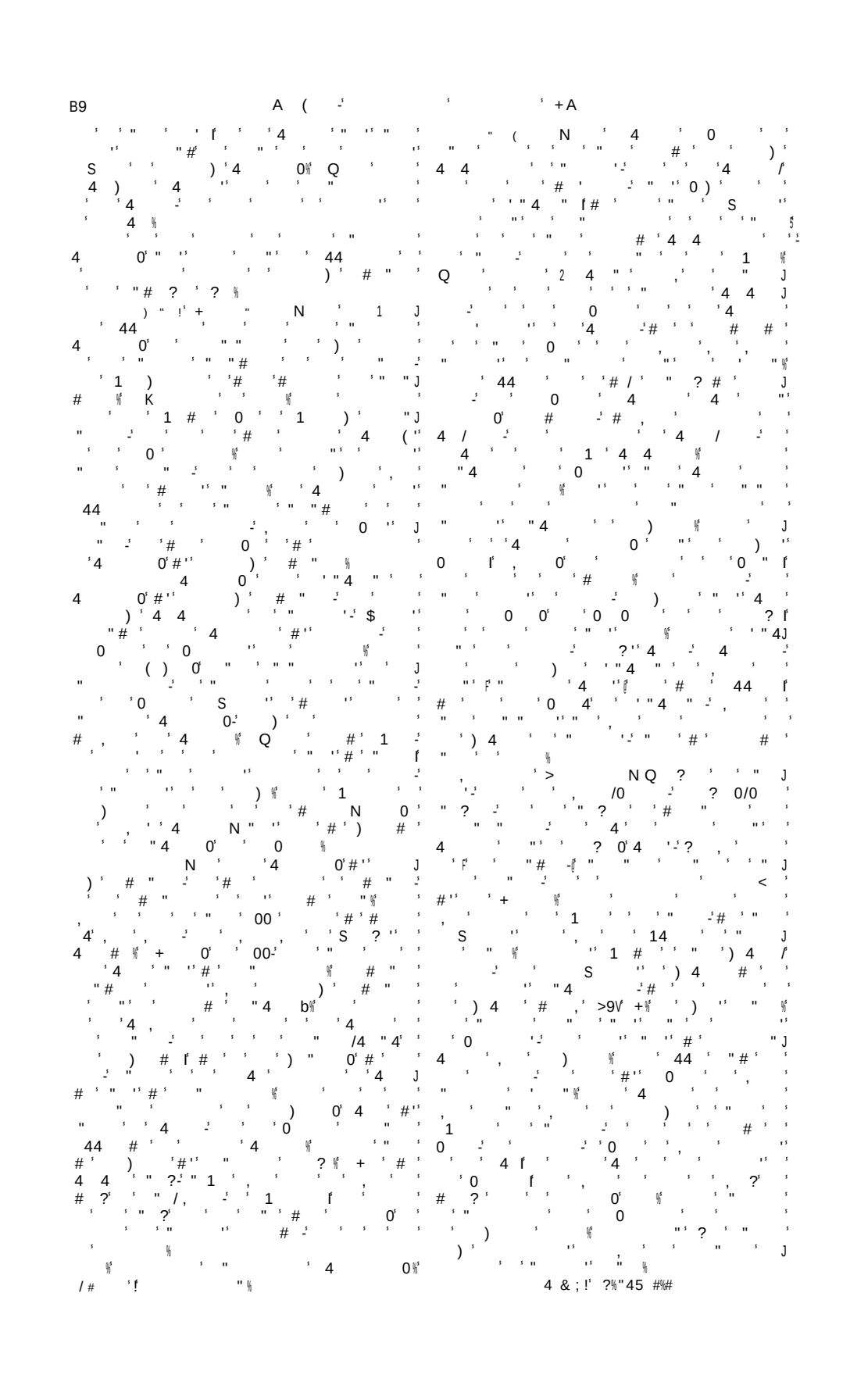

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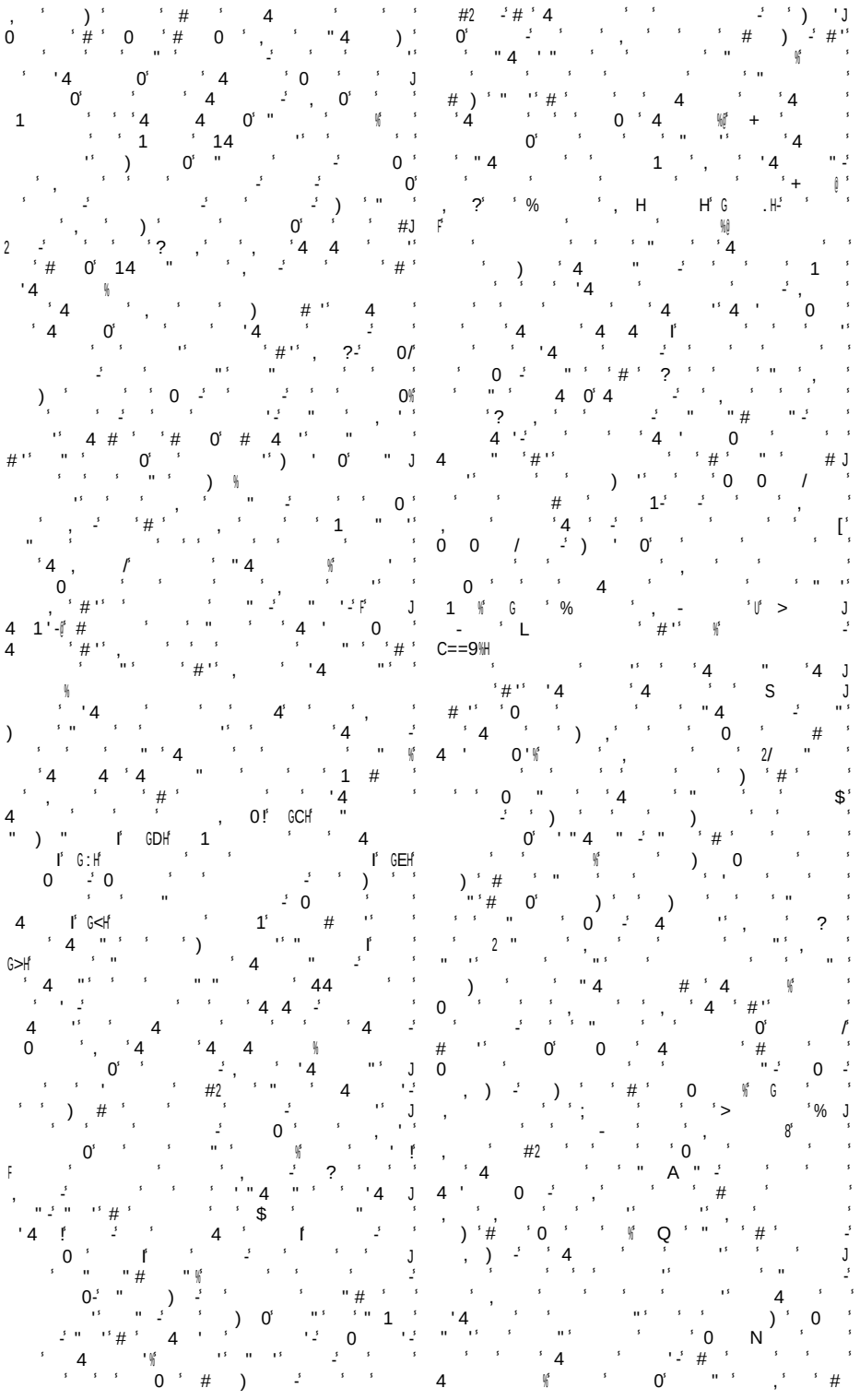
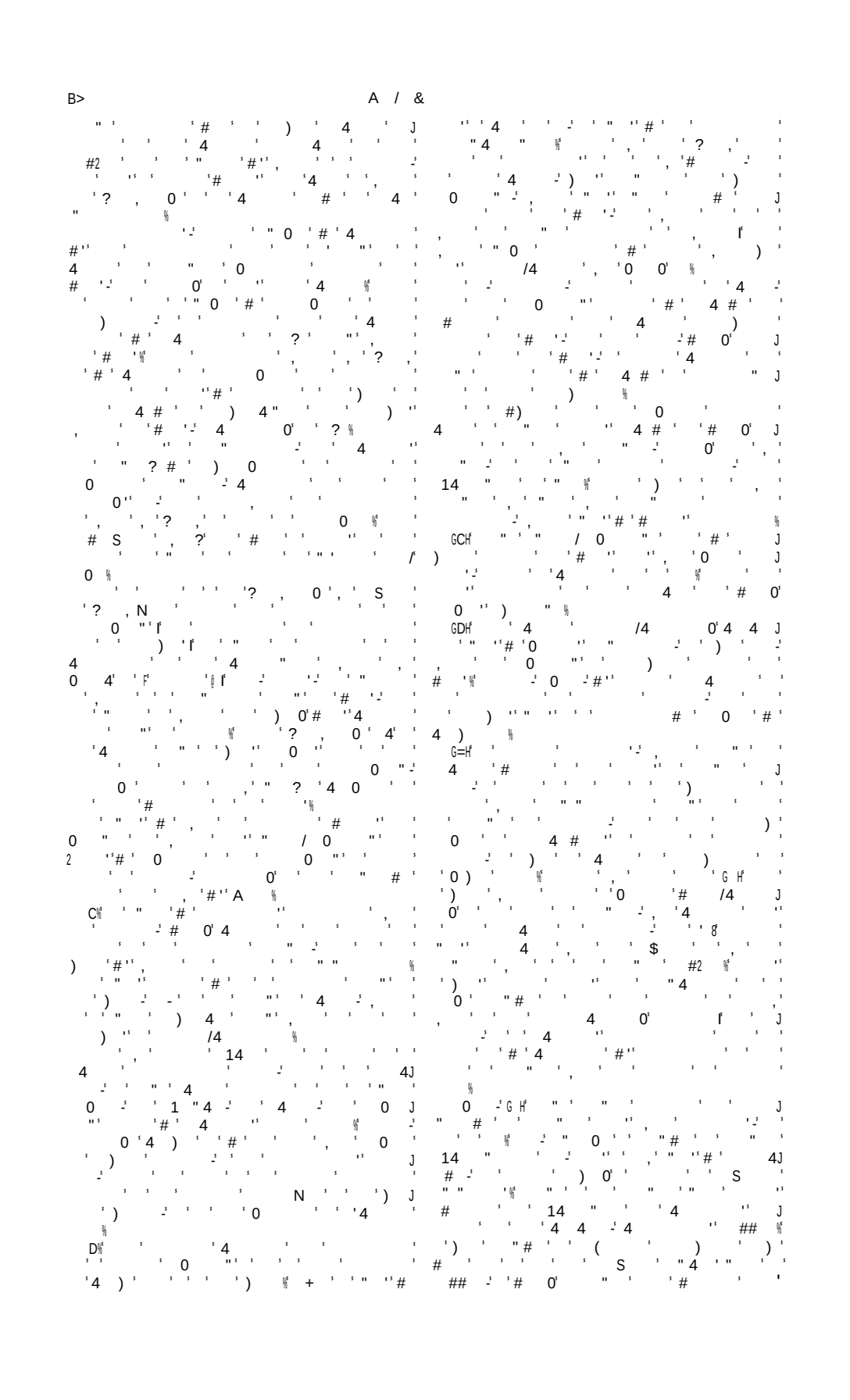




in some species, a great tendency to swell and undergo partial solution, or rather to form a gummy or jelly-like material, like gelatine or gum-tragacanth when soaked in water.

To the partial solution of this material is due the hyaline 'capsule' which is characteristic of some bacteria (*e.g.* the pneumono-coccus of Friedländer), and the intercellular substance of 'zoogloea' masses, by which the masses adhere to surrounding objects and cohere into a sticky mass.

Motility.—Many bacteria are spontaneously motile; indeed, the property is so common in several of the species associated with decomposition in organic fluids, that it was at first thought to be almost universal. But we now know that many never display this property.

Where present, it has in several species been long known to be associated with the presence of cilia or flagella, whilst in others no cilia could be detected, and it was believed that the movement of the cell-body itself sufficed to produce independent locomotion.

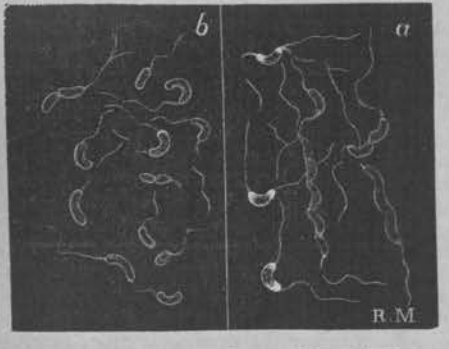


FIG. 68.—Finkler's Spirillum and Koch's Cholera Spirillum, both prepared in the same manner, stained by Löffler's method, to show flagella; and placed side by side for comparison. × 2,000 diam.—*a.* Finkler's Spirillum. From a culture made in the Pathological Laboratory, Univ. Edin. *b.* Koch's Cholera Spirillum. From a specimen from the Berlin Health Laboratory.

But from recent researches by a method devised by Löffler (for details, see *Staining of Bacteria*), aided by photomicrography, we know that flagella are present in several forms where they were hitherto invisible, for instance, the cholera spirillum; and we are not as yet entitled to assume their absence in other motile forms.

The flagella are apparently continuous with the cell-envelope; whether with the cell-protoplasm also is not certain.

Forms of the cells.—The cells are spherical, ovoid, or cylindrical, and usually symmetrical. They may be in short cylinders, bulged in the centre and somewhat pointed at the end (*clostridium* form). The cylinders may be short or long rods, straight or slightly curved (*bacillus* form), or much curved (*spiral* form). They may grow into long threads, straight, or curved, or twisted (*leptothrix* form, *vibrio* form, *spirillum* form, &c.), and appear to be homogeneous throughout; but in most cases we may by reagents discover that the apparently uniform thread is composed of cells arranged endwise, but remaining attached to each other. Such elongated forms are especially seen when growth occurs in fluids at rest.

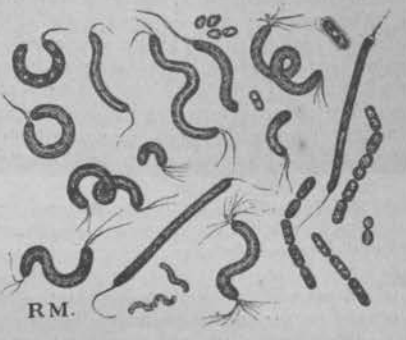


FIG. 69.—Spirillum Undula.—From a culture, stained by Löffler's method for showing flagella. The various forms and stages, and also the variety in number of the flagella, are seen. × 800 diam.

Position and arrangement of flagella.—Flagella have been discovered in several of the rod and spiral forms, and in one species which is spherical or nearly so (*Micrococcus agilis* of Ali Cohen).

In some of the lower and simpler forms (*i.e.* excluding Beggiatoa, &c.) the flagella are terminal and single only at one end of the cell; but in some there is one flagellum at each end. More rarely, two or more are present at one end. They are often long, and may greatly exceed the cell in length. They are usually of extreme tenuity (*e.g.* $\frac{1}{3}$ to $\frac{1}{5}$ the diameter of the cell in the cholera bacillus), and hence are detected with great difficulty.

In typhoid bacilli, in which Löffler was unable to detect flagella, a very remarkable condition has been discovered, namely, the presence of multitudes of short lateral cilia along the entire length of the cells. A similar condition has also been more recently detected in one or two other species.

Colouring matters.—Many bacteria, when grown in mass, show distinctive colours—red, yellow, brown, &c. These may develop only in certain conditions of growth, or in parts exposed to the air. On examination with the microscope, the pigment may appear to be in the cells (as in magenta micrococcus); but it is readily dissolved out, and would appear in most cases to be an excreted or formed product, which mainly lies in the intercellular substance, staining the cell wall. Or it may in some be the

product of some substance excreted by the cell acting on the culture-medium, and especially in presence of oxygen.

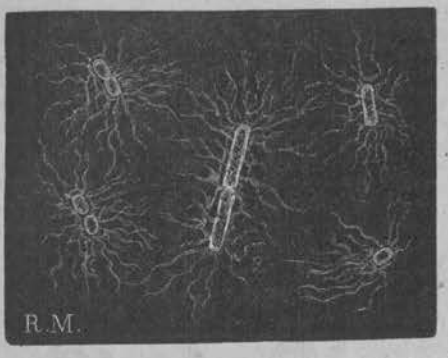


FIG. 70.—Typhoid Bacilli.—Stained to show cilia. × 2,000 diam. From a specimen prepared in the Berlin Health Laboratory.

Multiplication and fission of the cells.—Division occurs by fission, usually dichotomous, the segments being often of nearly equal size. This is usually preceded by elongation of the cell, so that in the spherical forms, as fission becomes complete, each of the new cells is nearly spherical before separation occurs. Transverse fission is the rule in the simpler rod and the spiral forms. But in some spherical forms it may take place in two planes at right angles to one another, hence forming tetrads (as in *M. tetragenus*, *M. gonorrhœæ*); or, further, in three different planes and directions at right angles to one another, forming a bale-like mass (*sarcina* form).

During the process of fission, a constriction may appear at the line of approaching segmentation, or none may be seen; hence different characters, especially in the elongated forms. The first cells may remain united in chains, threads, or groups, and may thus give special characters, from which names have been derived. But since such persistent union is inconstant, varying with the conditions of growth, and best seen in quiescent growth in fluid or semi-fluid media, it should not be regarded as other than a subordinate character. For example, all micrococci, if growing freely and kept in motion, must become 'diplococci' during the stage of division.

In bacilli the cells elongate, and if the segments do not separate they come to form threads. These threads do not form false branching, as occurs in the case of cladothrix.

Spore-formation.—The production of spores, and the properties with which these are endowed, are amongst the most important facts concerning bacteria. Discovered at first in some of larger size, such as the hay bacillus and anthrax bacillus, by Koch, the process is now known to be common to many of the straight, and some of the curved rod forms. For the latter there is less evidence, and the question is at pre-

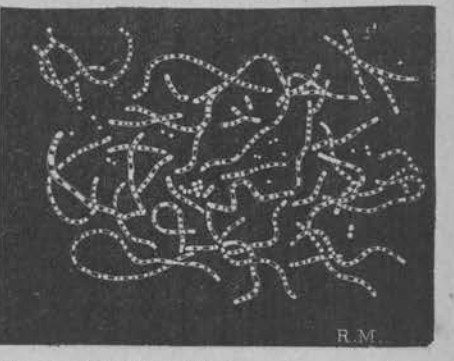


FIG. 71.—Cladothrix dichotoma. From a culture. × 800 diam.

sent unsettled for most spherical forms. But from known facts in the life-history of many species in which the existence of spores is not proved, there is strong probability that for all the rod forms, and very possibly all curved and spherical too, there is a like capacity, given favourable conditions of life.

The process of spore-formation takes place only under certain favourable conditions, and may be prevented by growth under unfavourable conditions, especially of temperature. It was formerly believed that spore-formation occurred especially when the nutriment was deficient, but there is now no question that it is a normal phase of their life, occurring especially under certain favouring conditions of growth.

Mode of spore-formation.—This can best be studied in some of the larger bacilli, such as the *Bacillus subtilis* and *B. anthracis*. The protoplasm of the cell appears to undergo condensation, its more solid portion becoming agglomerated and retracted, usually towards one end of the cell. At the same time it becomes more highly refracting, and often assumes different staining properties. The remainder of the cell may appear hollow or granular, but this is not always the case. Swelling may and frequently does take place at the site of the spore, so that the rod appears beaded. This swelling may be so considerable that the diameter of the spore may be twice as great as that of the rod, or more (*e.g.* tetanus bacillus). This fact is very apt to be exaggerated, owing to the different refraction of the spore and the rest of the protoplasm, which renders it difficult both to estimate and to photograph.

The spores are usually ovoid, more or less elongated, sometimes nearly spherical. When formed within bacilli arranged in chains, it commonly happens that the spores are situated one at the end of each cell, and

in such a manner that the cells form pairs with the spores at the adjacent ends. If now division of the cells takes place between the adjacent spores, rods imperfectly divided

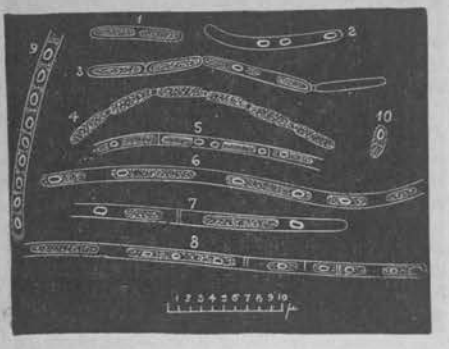


FIG. 72.—Stages in the Growth of a Bacillus, and of Spore-formation.—(1) Bacillus as seen before division; (2) Undivided bacillus showing spores; (3) Thread formed of segments, which have not separated; (4) Another of the same; (5) Part of a long filament, showing the lines of cleavage; (6) Another filament, showing aggregation of the protoplasm, and commencing spore-formation, without any sign of segmentation; (7), (8), and (9) show other appearances in undivided filaments; (10) Bacillus in process of growth from a spore. ×1,500 diam.

will be formed with a spore at each end; if at the end distal to the spores, a pair of spores will be seen near the centre of a rod. When the division is complete, each rod will contain a single terminal spore.

This fact, trivial as it may appear, is important to note, since distinctions of specific value have been adduced from this common fact.

Much less frequently the spores are situated towards the centre of the cell, or, in an apparently undivided rod, at irregular intervals. All these modes of arrangement may be seen in the same species, and they have no specific value.

Structure of the spores.—Beyond the facts that they consist of a highly refracting protoplasmic mass, with great endowments of vitality and peculiar staining reactions, surrounded by a capsule or cell-wall resembling that of the parent cell, but of greater resisting capacity, we know nothing. That they have an intimate organisation we suppose from what we know of other cells.

Staining reactions.—It has already been stated that the staining reactions of the spore protoplasm differ from those of the cell protoplasm, and may do so to a remarkable degree. By selective staining the spores may be stained of a different colour from the rest of the cell. And it may here be mentioned that in one of the common bacteria of water the spores show normally a definite coloration of a reddish tinge (*Bacillus erythrosporus*), when examined fresh, without staining.

Germination.—When placed under favourable conditions the spores germinate, and reproduce cells like those from which they originated. According to some, this takes place by a sprouting through the capsule; whilst others allege that the entire spore elongates to form the new cell, which then multiplies by fission. Except as possibly giving a clue to the structure of the spore, the question is unimportant. What is of consequence is that the spore always gives rise to cells like those from which it sprang.

Vital capacity of spores.—The remarkable power of resistance of the spores of many species will be referred to under the life-history in general, and in relation to particular species.

CLASSIFICATION OF BACTERIA.—We are now in a position to refer briefly to the classification of bacteria. Many attempts have been made to arrive at some satisfactory division, but hitherto with very limited success. The difficulty arises in great measure from our defective knowledge of their complete life-history, and of the variations which they may show under varying conditions of growth. Most of the attempted classifications are valueless for our purpose, and are also unscientific. The only true basis is of course a botanical one, and such properties as the production of colour, of fermentation, or of disease are useless, unless as provisional. We may therefore omit all mention of these. For the more recent scientific classifications botanical works may be consulted. For our purpose it is sufficient to adopt the nomenclature usually employed, it being understood that the names given are merely convenient appellations, and not scientific distinctions.

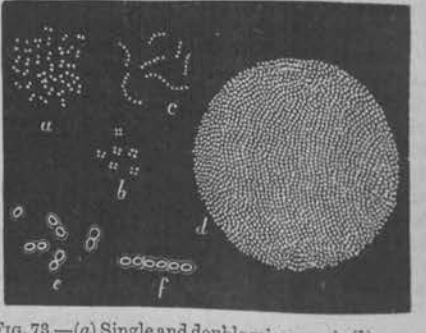


FIG. 73.—(*a*) Single and double micrococci; (*b*) groups of four, 'sarcina' form; (*c*) chains; (*d*) zooglœa; (*e*) single and double micrococci, more highly magnified, showing process of division; (*f*) a chain, more highly magnified.

The basis of this nomenclature is the form of the cells, and the arrangement commonly seen in their growth:—

(1) Spherical or slightly ovoid cells. *Cocci* or *Micrococci*—

Cells usually in pairs—*Diplococci.*

Cells in chains—*Streptococci.*

Cells in groups of four—*Tetragena* or *Tetracocci.*

Cells in bale-like masses, comprised of groups of eight—*Sarcinæ.*

Cells in masses or balls—*Staphylococci.* (Grape-bunch like.)

(2) Elongated, rod-shaped, or thread-like cells—*Bacilli.*

(3) Curved rods or filaments—*Spirilla.*

Various names have been employed to distinguish abruptness of curve, length, &c., as Spirochæte, Leptothrix, &c., but they are of no practical value.

But, whilst these names suffice for our purpose, it must be understood that, in dealing with bacteria as a whole, much more elaborate distinctions would be essential.

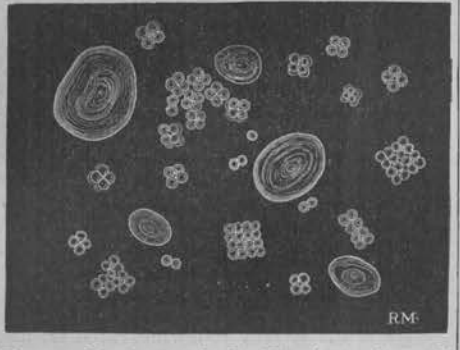


FIG. 74.—Sarcina ventriculi. Showing sarcinæ and starch-granules in vomited matter. ×400 diam.

CONSTANCY OF SPECIES. — *Variation or transmutation.*—Amongst the very important questions which underlie the subject of the pathogenic activity of bacteria, is that of the constancy of species, the possible variation under cultivation, and the acquisition or loss of specific activity.

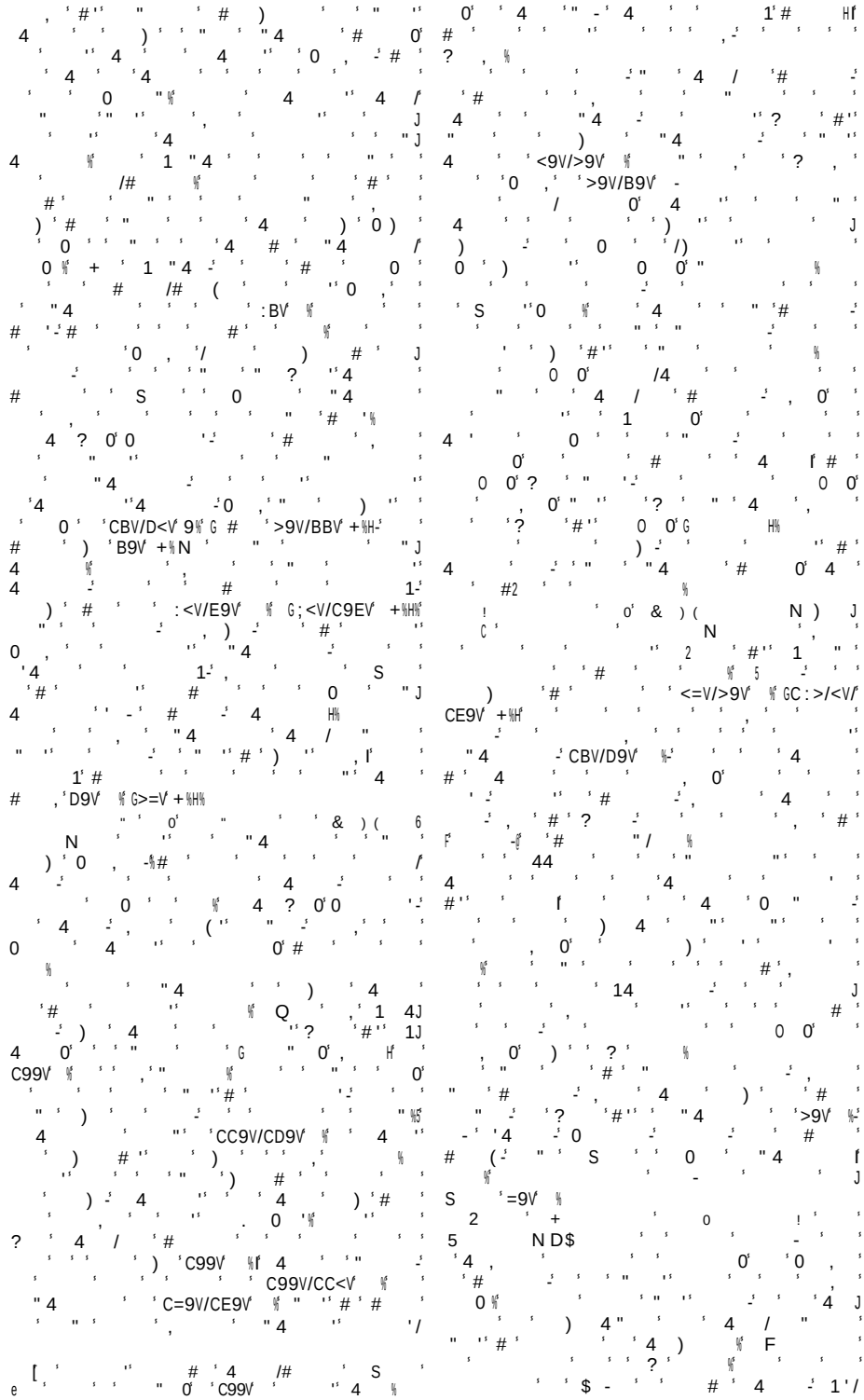
If marked variation or transmutation can occur, and if one species can not only pass into another, but can under varied conditions of life assume different capacities for fermentative and like activities, then not only is the subject rendered far more complex, but the relation of bacteria to virulent diseases is put on an entirely different footing. For they may be not so much the essential virus as the carriers of contagion, carrying in, as it were, a catalytic process from one individual to another. If, for example, a common bacterium, innocuous in itself, were liable, when grown in the blood of an animal suffering from some disease, to carry on the ferment-like activity of similar kind to another animal, it is obvious that the bacterium is not the specific virus. It simply transmits a process. Analogies to such a process may be found even in that of crystallisation. But if one species can do this, another may also; and so a similar disease-process might be secondarily induced by a variety of bacteria.

Two questions then arise: Are the species essentially and persistently distinct? Are the specific pathogenic activities innate or acquired?

VARIATION OF SPECIES.—From what we know of the variations of low organisms under cultivation, we should anticipate a high degree of capacity for variation or mutation in bacteria. Nevertheless, the amount of such variation appears to be small. For we find that a large number of species, which have been cultivated through hundreds of generations, not only maintain their morphological characters, but produce like effects as to colour production, fermentative changes in the cultivating media, and even pathogenic results. It has already been mentioned that differences are observed in the characters when grown under different conditions, but these do not impair the reproduction of the original characters when sown again on the original soil. Some characters, such as colour production or special fermentations, may only appear when special conditions are present.

It must, however, be stated that the pathogenic activity is capable of diminution or loss, and, conversely, of intensification, as will be seen in some cases to be mentioned. But this appears to be explicable rather on the hypothesis of acquired habit of growth, than of actual alteration or loss of capacity, and in some cases is associated with lowered vitality of growth. When re-acclimatised in the body, the virulence may be speedily regained. There is further the question whether great mutations of form, from spheres to threads, from these to spirals, and the presence or absence of cilia in the same species under different conditions, do not militate against the view of the specificity of bacteria. The answer to this is that in the lower fungi not only are great differences of form observed in the same species at various periods of life, but that two or even more modes of reproduction normally occur in some which have been carefully studied—resting spores and motile or free-swimming spores, for example, as in Saprolegnia. The discovery, then, that a species of bacterium exhibits great variety in its form, &c., at different periods of life, only shows that it belongs to one of the higher groups, in which such cyclical changes are part of the normal life-history. It is partly on this account that the lower forms, with which we are mainly concerned in disease, should be kept distinct from the higher groups in which such multiplicity of form is normal.

TEMPERATURE IN RELATION TO GROWTH.—The temperature of cultivation has been



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alleged by some, there is as yet no sufficient evidence of bacterial origin.

And it seems desirable to append a brief account of the micro-organisms of malarial fevers, although they are not bacterial in nature.

GROUP I.—*Suppuration, Pyæmia and Septicæmia, and 'Wound-Infection Diseases' in General.*—This group includes those common 'septic' conditions which are frequently the sequel of wounds and allied conditions. They are usually associated either with suppuration or spreading inflammation, and more or less intense blood-poisoning. They are produced by various bacteria, of which some are common, others rarer causes. To some extent the form of disease produced is dependent on the mode of introduction or on special conditions which modify the action of the virus. Thus, the organism of osteomyelitis can produce ulcerative endocarditis, as can also certain other bacteria. What we call erysipelas may be produced by various bacteria, *e.g.* experiments on the lower animals have shown that the bacillus of mouse-septicæmia, a blood-disease in mice, causes local erysipelas in the ear of a rabbit. But in man, experience shows that the commonest causes are few and well defined.

Under this head should also be included the various forms of Infectious Gangrene, such as 'hospital' gangrene, cancrum oris, &c. But our knowledge of these conditions is, as regards man, too incomplete to allow of any definite statements, and we have therefore not discussed it separately.

1. Suppuration, Pyæmia, &c.—To avoid ambiguity, it may be stated that we look upon suppuration as a sequel of inflammation under certain circumstances in which, by gradual accumulation of leucocytes which have passed from the blood-vessels, and gradual liquefaction of the tissue-elements, the part affected becomes occupied by the cream-like fluid known as pus. Such a process, after starting at one point, may spread to a greater or less extent, and sometimes occurs in association with similar lesions in various parts of the body. Suppuration is accordingly to be distinguished from those conditions in which, by the action of a severe irritant, a co-extensive local necrosis of the tissue occurs, which may afterwards undergo some softening. Some of the most important questions in connexion with this subject are: Can suppuration occur apart from the action of micro-organisms? What organisms are generally concerned in the process? And what is the relation of strictly local abscess-formation to those conditions in which so-called metastatic abscesses occur, and which are commonly grouped under the head of *pyæmia*?

Whilst various pyæmic conditions present the characters generally associated with diseases of bacterial origin, the theory that suppuration is in all cases caused by micro-organisms might *à priori* be open to doubt. Partly, however, as the result of early bacteriological investigations, partly as the result of the antiseptic treatment of wounds, the belief gained a wide currency that without bacteria suppuration could not occur. Within recent years, extensive series of experiments have been performed by various workers in order to determine whether suppuration can be produced by a simple chemical substance. The methods of performing these experiments have been various. In some, the substance to be tested was simply injected under the skin with antiseptic precautions, the puncture being closed immediately afterwards; but as this was open to certain objections, the method was devised of placing the chemical substances in sealed glass tubes, which were introduced into the tissues, and were broken after the external wound had healed. In others, again, the tubes had sharp ends, so that after a time they could be moved under the skin to another part of the body and there broken. Though it has been clearly proved by such experiments that in most cases suppuration does not follow, and that its occurrence is not dependent upon the intensity of the irritant, yet many observers (Councilman, Grawitz and De Bary, Steinhaus, Christmas, and others) agree in finding that certain chemical substances (*e.g.* nitrate of silver, mercury, &c.) can produce local abscesses, whose contents can be shown by inoculation on culture-media to be free from the ordinary pyogenic organisms. Amongst the substances found to be capable of producing suppuration in this way are the chemical products of several of the pyogenic bacteria.

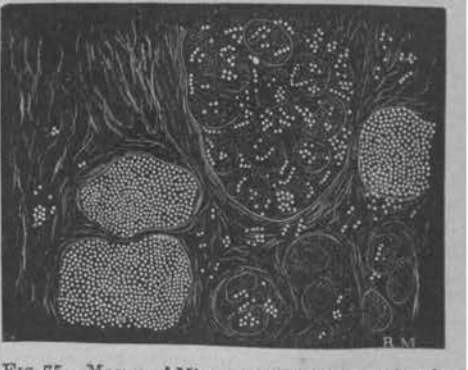


FIG. 75.—Masses of Micrococci (Staphylococci probably) in the vessels in 'surgical' kidney.

But even if it be admitted that pus, with all its essential characters, can be produced by the action of a simple chemical agent, much more important questions must be

answered, namely, What are the actual causes of suppuration as met with clinically? What organisms are present? and Have they pyogenic properties?

Amongst the first to demonstrate the presence of bacteria in ordinary suppuration was Ogston of Aberdeen, who, in a paper published in 1881 (*Brit. Med. Journ.* 1881, i. p. 369), described the practically invariable presence of micrococci in acute abscesses, and affirmed them to be the causal agents in the process. Some of these organisms, from their growing

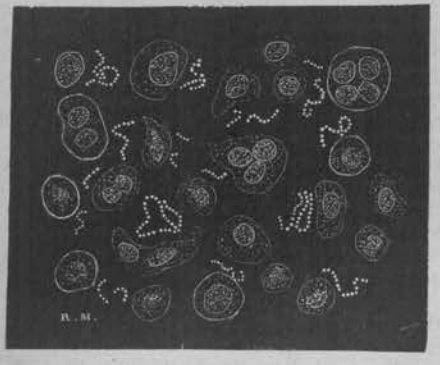


FIG. 76.—Streptococci in Fœtid Sputum. × 800 diam.

in the form of clusters, he called *Staphylococci*; to others which grew in the form of chains he applied the name *Streptococci* (previously given by Billroth). The former he found to be specially associated with circumscribed abscesses; the latter with spread-

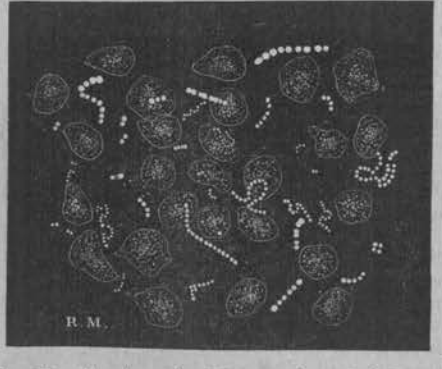


FIG. 77.—Streptococci of Suppuration.—Dried pus from an empyema of some duration. Showing chains of streptococci, some of which are swollen, probably from degenerative changes. × 800 diam.

ing erysipelatoid suppurations—facts which have since been confirmed ('Micrococcus-Poisoning,' *Journ. Anat. and Phys.* 1882-3). Shortly afterwards Rosenbach (*Mikroorganismen bei den Wund-Infectionskrankheiten des Menschen*, 1884), by means of solid culture-media, obtained pure growths of these organisms, and separated several distinct species. The three most important of these he called *Staphylococcus pyogenes aureus*, *Staphylococcus pyogenes albus*, *Streptococcus pyogenes*; whilst another, less frequently met with, he called *Micrococcus pyogenes tenuis*. Other organisms have been found in acute abscesses, *e.g. Staphylococcus pyogenes citreus*, *Staphylococcus cereus albus*. *Staphylococcus cereus flavus*, *Bacillus pyogenes fœtidus* (Passet, *Fortschr. d. Med.* 1885, Nos. 2 and 3), *Bacillus pyocyaneus*, &c.

Staphylococcus pyogenes aureus.—The most frequently present of these organisms, and that which has been the subject of most investigation, is the *Staphylococcus pyogenes aureus* (yellow cluster-coccus, *Gelbtraubencoccus*). This organism, when grown on culture-media, has certain characteristics which render its recognition comparatively easy. In puncture-cultivations on gelatine, growth is seen first (in about twenty-four hours at the ordinary temperature) as a greyish-white line along the needle-track. The growth soon assumes a yellowish colour, and, as liquefac-

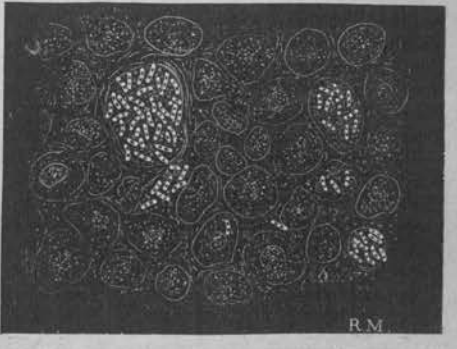
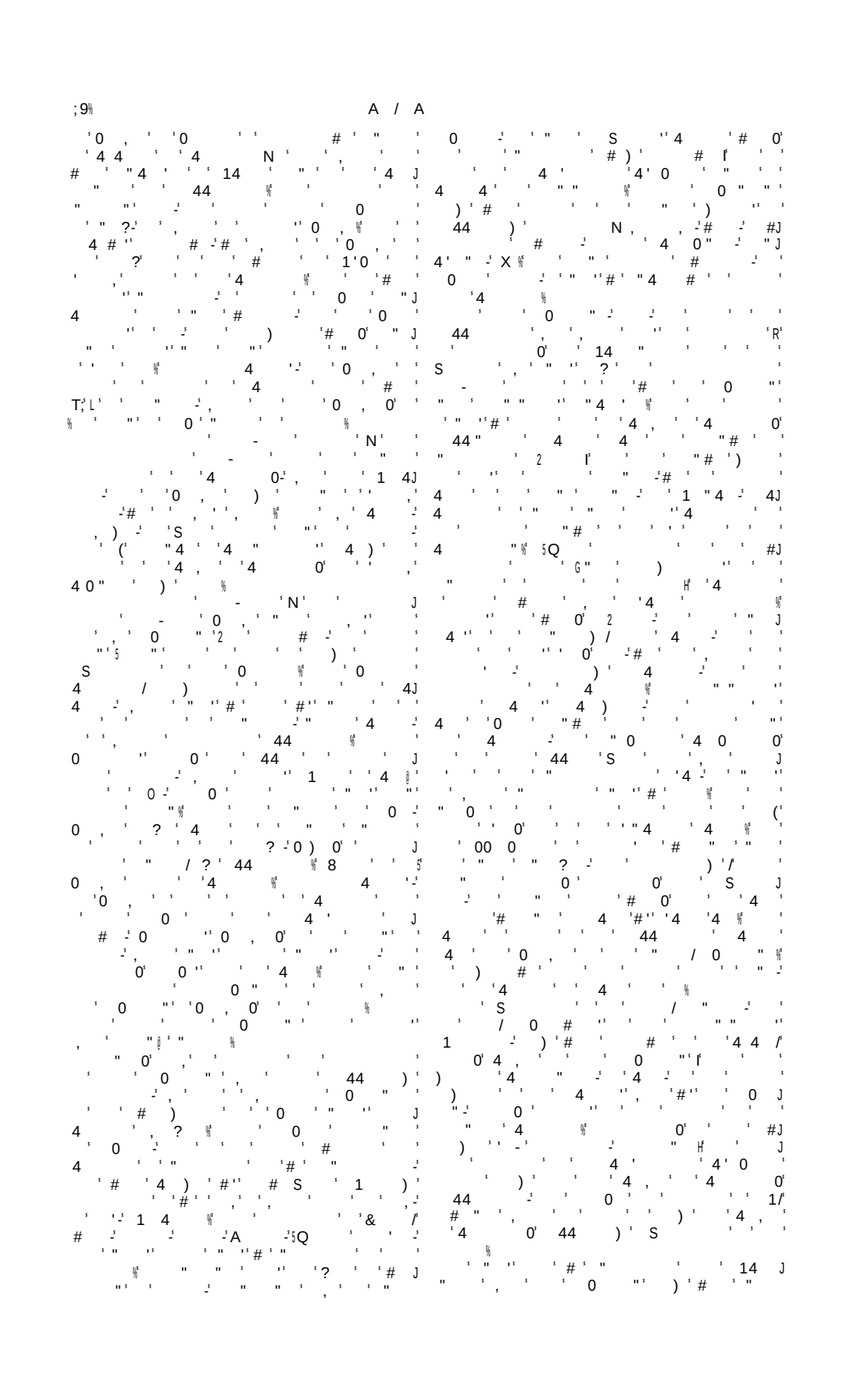


FIG. 78.—Multiple Suppurative Septic Nephritis ('Surgical Kidney').—Shows short bacilli in capillaries and in cells. × 800 diam.

tion of the gelatine rapidly occurs around it, forms a flocculent mass at the junction of the fluid and solid portions, being afterwards of bright orange colour. If a stroke-cultivation be made on agar a similar growth takes place along the line, which soon shows a bright orange colour; and as its surface is smooth and shining, its appearance has been aptly compared to a streak of orange oil-paint on the surface of the medium, which does not undergo any liquefaction. It also grows on potatoes, producing here also the characteristic yellow colour. Its growth on these media after a few days has a peculiar sour smell. On gelatine-plates it grows as minute round points, which soon reach the surface, and then liquefaction occurs around them, so that small masses of growth are seen lying in small cups, the centres of growth having by this time acquired a yellowish colour. In



on the human subject. Garré (*Fortschr. d. Med.* 1885, No. 6) inoculated Staphylococcus pyogenes aureus on a few small scratches near the root of the finger-nail, and produced a small cutaneous abscess; and by rubbing a cultivation on agar into his arm he caused a carbuncular condition, which only healed after some weeks. Bockhart and Bumm have confirmed the observations of Garré.

Staphylococcus pyogenes albus has the same pyogenic properties, but many observers have found that it is less virulent in its action. *Streptococcus pyogenes* in its growth in the tissues has rather a tendency to spread by the lymphatics over a wide surface, than to form a local abscess. It causes suppuration when injected into the serous cavities and joints, and clinically is often met with in those positions when suppuration is present. Several other organisms have been proved to possess pyogenic properties.

Injection of Staphylococcus pyogenes aureus into the blood produces effects according to the dose: if the amount be small no result may follow, if very large the animal dies with septicæmic symptoms within a few hours. If the animal survive a large injection for more than a day, changes often occur which form a type of what is seen in various pyæmic conditions in the human subject. For a time after the injection the organisms can be found in the blood, but they gradually disappear from it, and are found in the capillary walls, kidneys, liver, &c. According to Lübbert (*Der Staphylokokkus pyogenes aureus, &c.* 1886) and Krause (*Fortschr. d. Med.* 1884, Nos. 7 and 8), they also pass into the urine, and can be cultivated from it; but this probably occurs only after the organ-

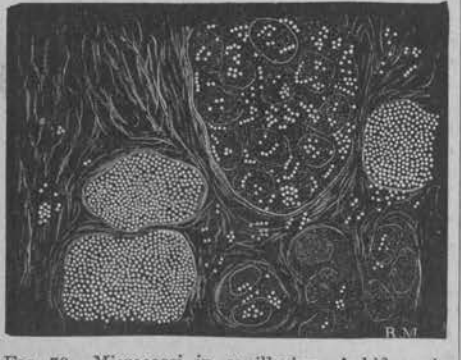


FIG. 79.—Micrococci in capillaries of kidney in Multiple Septic Abscess. Showing masses of cocci like Staphylococcus pyogenes aureus.

isms have actually grown into the tubules, and cannot be regarded as a true excretion, as some have supposed. Of the changes found after twenty-four hours, the most constant are those in the kidneys. Under the capsule are seen a number of paler points, surrounded by a zone of intense injection, and corresponding to those there are found on section numerous areas of pyramidal or oblong shape in the cortex, while in the medulla pale streaks or lines of pale dots are seen running between the tubules. Microscopically, many of the small arteries and capillaries in these areas are seen to be plugged with collections of micrococci, whilst these are also found in the lining of other vessels, both arteries and veins. In the tissue surrounding these vessels micrococci may be found, and the cells of the tubules show necrotic change, while at the margin infiltration of leucocytes is seen. Later the affected areas undergo purulent infiltration and softening, and form small abscesses. Quite analogous changes are found in other parts of the body, though less constantly than in the kidneys. In the muscle of the heart small vessels may be plugged in the same way, the fibres around being the seat of necrotic change with infiltration of leucocytes, leading ultimately to foci of acute suppurative myocarditis. Abscesses are also occasionally produced in the ordinary striped muscles, in the joints, under the periosteum, and in the medullary cavities of bones.

Similar phenomena are sometimes observed in the human subject in cases of ulcerative endocarditis and osteo-myelitis; and though ordinary pyæmia presents some differences, these are to be explained by its method of production. In pyæmia the series of events generally starts with a septic phlebitis caused by an external wound, and associated with the formation of a thrombus which afterwards softens and becomes the source of emboli. The softening of the thrombus is for the most part due to pyogenic organisms, though others may be associated with them; and as the portions of softened thrombus are in the course of the circulation carried first to the lungs, and there plug the pulmonary vessels, pulmonary abscess is an almost constant feature in the common form of pyæmia. In experimental intravenous injections of staphylococci, on the other hand, points of suppuration are very rarely found in the lung, as the organism seems unable of itself to gain a foothold and flourish in the lung-tissue. Various organisms have been cultivated from pyæmic abscesses and from the blood in pyæmia, but by several observers a streptococcus has been found to be most frequently present, and Rosenbach considered it the chief organism concerned, though not regarded as specific. The rare occurrence of 'metastatic' phenomena in the course of ordinary suppuration is probably to be explained by the fact that, even if a few organisms do enter the blood, their growth is arrested by the bactericidal power of the serum and leucocytes, as is shown by direct experiment. If, however, there be a weak

the skin of pure cultivations of the Streptococcus erysipelatis, some of these being cultivated through many generations. A similar condition was also produced in rabbits, but many other animals appear not to be susceptible to the disease.

In erysipelas the micrococci grow in the lymphatic system of the cutis, and produce an inflammatory condition attended with exudation, indicated clinically by the well-known area of spreading redness with slightly raised margin. The micrococci are found in great numbers, growing in chains and singly, in the lymphatic spaces immediately beyond the swollen edge, often plugging the lymphatic channels. They are also found within the cellular elements of the part. As they spread by their growth they produce the usual phenomena of inflammation, attended with a considerable amount of exudation, which may coagulate. The tissue-elements undergo some swelling and may show some degenerative change, but no actual softening or liquefaction occurs as in suppuration. The micrococci rapidly break down and disappear after the inflammatory condition has been established, whilst they continue to multiply in the lymphatic spaces beyond the inflammatory margin. After a time their growth generally comes to an end, but the means by which this takes place cannot be discussed here. The growth of the organisms is practically confined to the lymphatic system, and although probably a few do enter the blood-stream, they do not appear to be able to multiply there, and cultivation-experiments both in clinical cases and in artificial inoculations have almost invariably failed to show their presence in the blood. The general symptoms, often of severe character, attending the progress of erysipelas, are most probably due to absorption of the products of the growth of the organisms in the tissues; and Manfredi and Traversa have found that the products of the growth of the erysipelas micrococcus when injected into animals cause grave nervous phenomena, partly of convulsive, partly of paralytic nature.

Fehleisen found that a patient who had suffered from erysipelas a short time before was insusceptible to fresh inoculation, and the same has been observed in the case of animals. This immunity, however, he found only to be of short duration, and this accords with the fact that erysipelas in the human subject may show a tendency to recur.

5. **Gonorrhœa.**—The first account of an organism peculiar to this disease is that of Neisser, who in 1879 (*Centralb. f. d. med. Wis.* No. 28) described a micrococcus, whose morphological characters and relations to the pus-corpuscles in the secretion served, he considered, to distinguish it from other organisms which might be accidentally present. He found it in the acute stage of the disease, both in the male and female subject, and also in gonorrhœal conjunctivitis, but in no other conditions. This organism is now generally known as the micrococcus of gonorrhœa, or Neisser's *Gonococcus*, and his statements have been in the main confirmed by other observers. Attempts to cultivate it followed, but we now know that many of the earlier statements with regard to pure cultivations of this organism are erroneous, as these were made on media on which it does not grow. Later, however, several observers, by using human blood-serum as the culture-medium, have succeeded in isolating the gonococcus, and in cultivating it through many generations; and inoculation-experiments on the human subject have practically proved it to be the cause of the disease. (*See* the papers of Leistikow, Krause, Bokai, Bockhart, and especially the monograph of Bumm, *Der Gonokokkus Neisser*, Wiesbaden, 1887.)

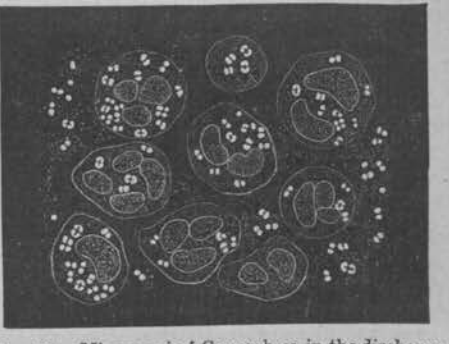


FIG. 80.—Micrococci of Gonorrhœa in the discharge from a case of acute gonorrhœa. The cocci are seen mostly as pairs or groups of four, and are mainly in the protoplasm of the pus-cells. × 850.

On microscopical examination this organism is found to be of the diplococcus variety, nearly all the cells being arranged in pairs, single spherical cocci being comparatively rarely seen. The two members of a diplococcus have often their adjacent sides flattened, or even slightly concave, so as to appear like two small beans placed side to side. In some, transverse division of the two halves is seen, and distinct tetrad forms thus occur (*see* fig. 80). They never grow in the form of chains. These characters, which are seen both in gonorrhœal pus and in cultivations, were at one time thought to be characteristic of the gonococcus, but have now been found to belong to many diplococci. The size varies according to the phase of development, but a fully formed diplococcus measures about 1·5 μ in length.

The micrococci of gonorrhœa stain readily with the basic aniline colours; and their presence in gonorrhœal pus can be very readily demonstrated by staining dried films for thirty seconds in a strong watery solution of fuchsin

acute infective disorders are sufficiently striking to encourage research.

Of the kinds of micro-organisms which have been discovered in the pneumonic lung, two have especially gained prominence, Friedländer's and Fraenkel's pneumonia bacilli. Both have been found in a large number of cases by various observers, but at present the evidence of the causal relation of either to the disease is not sufficiently conclusive.

Friedländer's pneumonococcus or, more correctly, bacillus, was the earliest discovered. He found it in the lung-tissue, especially in the exudation in the air-cells, and in the lymphatics of the affected lung, in very numerous cases, and it has also been very frequently found in the sputa. These bacilli were cultivated by Friedländer in various ways. His observations have been repeated by many others, and their substantial accuracy cannot be questioned, so far as the frequent presence and general characters of the organism are concerned. The writer has frequently cultivated them from sputa, and also from fluid aspirated from the lung and from the pleura in cases of acute pneumonia.

Their characters may be briefly described. As seen in sputa, sections of the lung, or cultivations, they consist of short oval or oblong cells, arranged singly, in pairs, or short rows. They approach so nearly to a spherical shape that they were described by Friedländer as micrococci.

Within the body and in sputa, many of them appear to be surrounded by a hyaline capsule or clearer space, which may include single cells or short rows, and may be specially stained. This character, which was regarded by Friedländer as distinctive, is now known to be present in many other bacteria, and is simply due to gelatinous softening of the cell-wall, as already described.

The organism may readily be cultivated on peptone-gelatine, at normal temperatures, though it grows better at 35° C. It grows especially well on the surface, producing an elevated rounded mass, which, with the growth along the needle-track, causes an appearance which may be likened to a nail or pin, a character regarded as peculiar by Friedländer. It does not liquefy the jelly. It grows also on potatoes and on blood-serum.

Inoculation with these cultivations Friedländer found to produce pneumonia and pleurisy in mice, with reproduction of the organism in the pleural fluid, the lung, and the blood. The spleen was greatly enlarged and indurated. In guinea-pigs and even in dogs similar results were produced, though exceptionally. Rabbits were unaffected.

It has been objected to Friedländer's experiments that the method adopted, by injection into the lung, was faulty, and only showed the production of septicæmia with local inflammation. Nor does the fact that in a small number of cases inhalation of the organism produced a similar effect remove this objection. It can only be said that this organism is poisonous to mice and causes intense local inflammation and septicæmia in them, but this in nowise suffices to prove its special relation to pneumonia. Moreover, an apparently identical bacterium, similarly virulent, has been cultivated from the secretions of the mouth of healthy persons, and appears to be commonly present there.

It was pointed out by Afanassiew that another bacterium, differing from the preceding in size and shape, was also often present in the lungs and the sputum in pneumonia. This, which has been more fully studied by A. Fraenkel and G. Weichselbaum, and is known as the Fraenkel or Fraenkel-Weichselbaum pneumonia bacillus, has been found

FIG. 81.—Acute Pneumonia.—Dried sputa from a case of pneumonia, showing the Streptococcus lanceolatus, and some other Strepto- and Diplococci. × 950 diam.

to be very commonly present in the lungs and in the rusty sputum in cases of pneumonia, especially during the earlier stages. From its shape it has also been called the Diplococcus lanceolatus, and is also known as the Diplococcus Pasteuri. It is in reality a bacillus. In shape it is like a short spindle partially divided into two halves, each of which is lancet-shaped. The double cells may form short chains. Like Friedländer's, this bacillus shows a capsule when within the body, but not in cultivations. It can be cultivated on nutrient jelly, agar, or blood-serum, and still better in broth. It grows best at about 35–37° C., but can be grown on jelly at 24° C. or a little higher, forming small, rounded, translucent, whitish points. It does not grow at ordinary temperatures; and this fact, along with its comparatively slow rate of growth, makes its cultivation more difficult than Friedländer's organism. When grown outside the body it rapidly loses its virulence, and also its vitality, unless fresh cultivations are made.

Inoculations with these cultivations cause

Nicolaier found a bacillus which presented peculiar characters, together with others commonly found in suppurating wounds. Inoculation of other animals with pus from the wounds gave rise to tetanus in them, with reproduction of the same bacillus, but not in a state of purity. Attempts to cultivate the bacillus proved unsuccessful. In 1886 Rosenbach found the same bacillus in the wound in a fatal case of tetanus in man, and produced tetanus by inoculation from the wound, and from impure cultivations from the bacillus at the fourth generation. And although Rosenbach did not succeed in cultivating the special bacillus in a pure condition, he was able to exclude the other forms present in the cultivations as causes of tetanus, by cultivating them apart and inoculating in other animals.

The first successful attempts to isolate and cultivate the tetanus bacillus were published by Kitasato in 1889 (*Zeitschr. f. Hygiene*, Bd. vii. p. 225). Cultivations of pus from a case of tetanus were allowed to grow for forty-eight hours at the temperature of 38° C. They were then exposed to the temperature of 80° C. for three-quarters of an hour to one hour. This had the effect of killing all except the tetanus bacillus (or its spores). Cultivations made from the residue in an atmosphere of hydrogen succeeded in peptonised broth, gelatine, or agar.

The bacillus thus obtained appears to correspond with that previously described by Nicolaier. It grows freely only in an atmosphere devoid of oxygen, and is therefore strictly anaërobic. That it can develop in the presence of other aërobic bacteria may possibly be due to their action in absorbing the oxygen. It grows best at a temperature of 36–38° C., the spores appearing at the end of thirty hours. Below 14° C. its growth ceases; between 20° and 25° C. it is very slow, and spores do not appear for seven or eight days. The spores show great resistance to heat and drying; a moist heat of 80° C. for an hour does not kill them, and the spores can be kept in a dry condition for some months, still retaining their activity. Water or steam of 100° C. kills them in five to fifteen minutes; steam at 115° in five minutes with certainty. Cultivations made in the manner described retain their virulence during successive generations.

When grown in gelatine-medium the colonies usually commence as slightly cloudy points, from which radiate very fine thread-like branches. Liquefaction occurs, but somewhat slowly. If any oxygen is present, the growth occurs most readily in the deeper parts of the cultivation.

The bacillus itself is very minute, and may be seen in rods from 3–5 μ in length, growing to filaments. The diameter averages about ·4 μ. The bacillus is slightly motile. In cultivations it forms spores which are nearly spherical or ovoid in shape, and exceed the rods in diameter, being sometimes more than four times as wide. Hence, when division occurs between the spores, as is frequently the case, the bacillus resembles a pin or tambour in shape, a point which has been regarded as characteristic. But whilst this fact may aid in its distinction amongst the bacteria from wounds, it cannot be considered as in reality distinctive from other bacteria in general; though there are other peculiar characters, as seen in the woodcut, not described in other bacteria, and new to the writer. The bacillus is readily stained by any of the ordinary methods with various aniline dyes.

The remarkable resistance of the spores has already been mentioned. Putrefaction

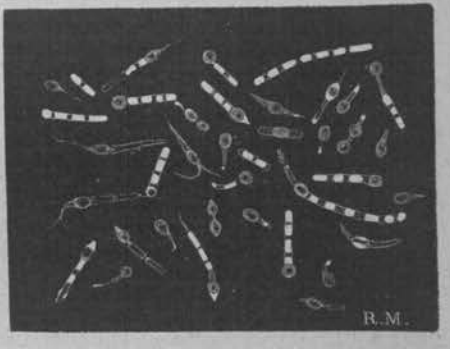
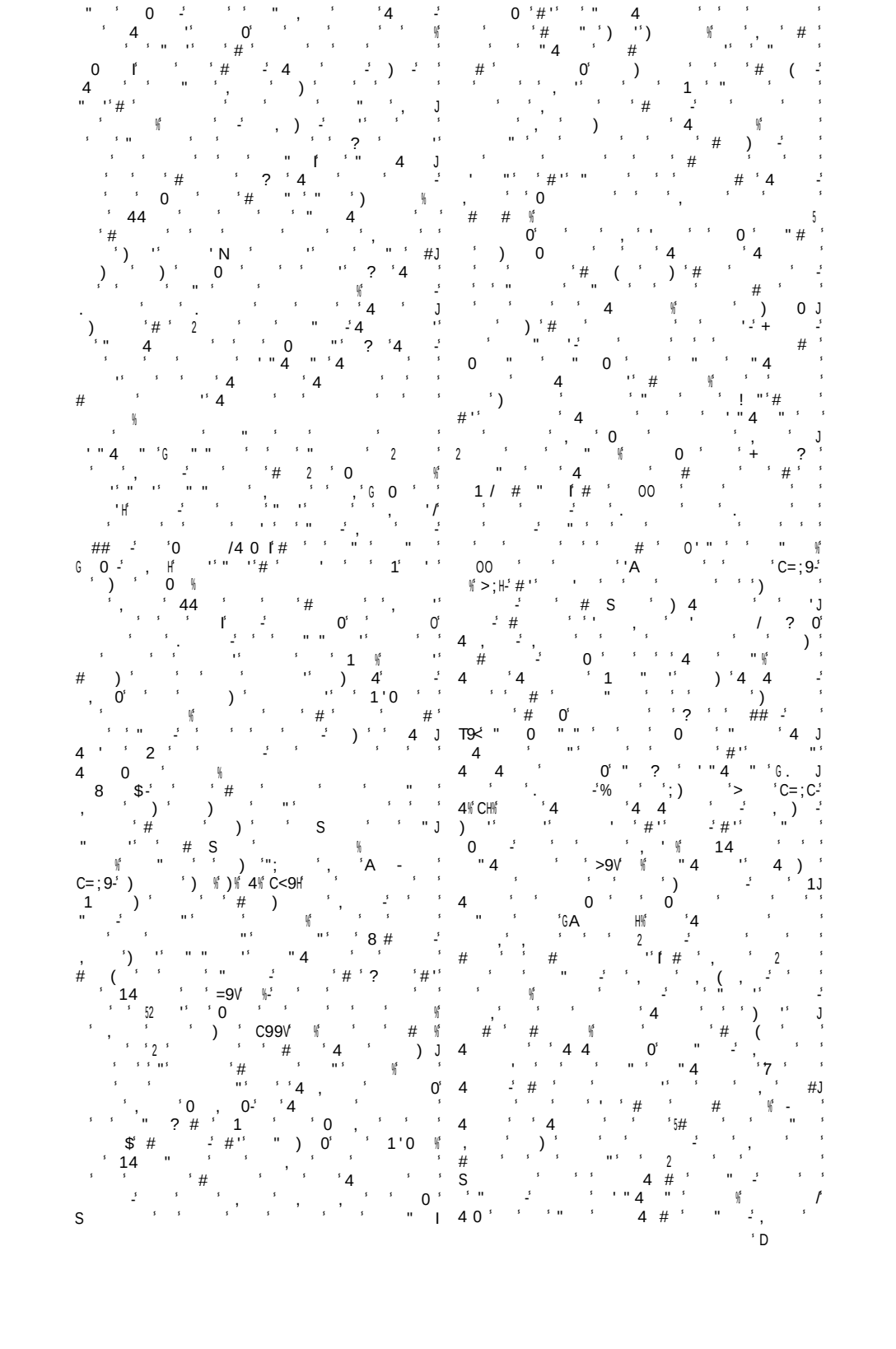


FIG. 82.—Tetanus Bacilli.—From a culture, stained by Löffler's method for showing flagella. From a specimen obtained from the Berlin Health Laboratory. Magnified 2,000 diameters. In addition to the peculiar shape, due to the large terminal spore, other peculiar morphological features will be observed: the character of the flagella, the apparent flagellation of the spores, and their relation to the bacilli.

of the tissues containing them does not affect them. Their degree of resistance to antiseptics appears also to be great. Carbolic acid (5 per cent.) applied for ten hours has failed to kill them, and corrosive sublimate, 1 in 1000, requires more than three hours (Sanchez Toledo and Veillon).

General relations to the disease.—Up to the present time there is some conflict of opinion as to the exact distribution of the tetanus bacillus within the body; but from a general summary, and especially from a valuable series of experiments by Sanchez Toledo and Veillon (*Arch. de méd. exp.*, tom. ii. p. 709, 1890), the following would appear to be the probable condition.

The bacillus when inoculated multiplies in the wound, especially in the deeper parts, producing some little irritation, but no suppuration, although this may occur from the presence of other organisms. It does not pass into the blood, or only in a very



presence of bacilli in tubercular affections, by isolating and cultivating these organisms, and lastly by inoculating with them and producing the disease. His work in this discovery is an excellent practical example of the canons laid down by himself for proving the bacterial nature of any disease.

The announcement of the discovery of the bacillus of tubercle was made by Koch in 1882, and a full account of his work appeared in the following year in the *Mittheil. a. d. Kaiser. Gesundheitsamte.*

For a time Koch's endeavours to demonstrate the presence of organisms in tubercle, by means of the methods of examination and staining then in use, were unsuccessful. But he ultimately found that by subjecting the tissues for a long time to the action of a solution of methyl blue, rendered alkaline by the addition of caustic potash, which increases its penetrating power, the presence of bacilli could be revealed. This original method was replaced by a better one, namely, the staining of the tissues for twenty-four hours with gentian-violet solution in aniline-oil water. He found that when stained in this way the bacilli retained the stain even if treated with strong mineral acids. By the employment of dilute nitric acid (one part in two of water) he could remove the stain from the tissues and other organisms, leaving these bacilli coloured. One exception he found, namely, the bacilli of leprosy, which react to the stain in the same way, though they hold it with rather less tenacity. He then coloured the tissues by a contrast stain, such as Bismarck brown. All other methods of staining subsequently devised depend upon the same

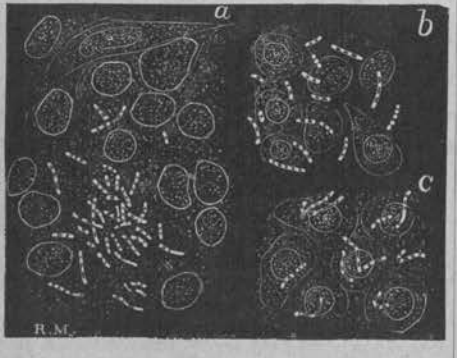


FIG. 83.—Tubercle Bacilli.—*a*. From section of lung. *b*. From sputum. *c*. From section of tubercular ulcer of intestine. × 850 diam.

principle, namely, that these bacilli can only be stained by a solution of strong staining power (generally a solution of fuchsin or gentian violet, with a suitable mordant), and when thus stained they can be subjected to powerful decolorising agents without losing their colour.

Characters of the tubercle bacillus.—The organism thus discovered by Koch, and now known as the *Bacillus tuberculosis* or *tubercle bacillus*, is of comparatively small size, measuring as a rule 2·5–4·5 μ in length, and about ·3 μ in thickness, so that relatively to its length it is a thin bacillus. The rods are straight or slightly curved. They are generally found singly; often two are joined in a straight line or at an obtuse angle; but in the tissues they rarely form longer rows, though these are common in cultivations. Occasionally in the tissues, very frequently in phthisical sputum, and also in old cultures, an appearance may be seen in the bacilli which suggests the occurrence of spore-formation. This consists in the presence of clear globular unstained spaces in the bacilli, there being sometimes three or four such in a single rod, and arranged so regularly as to give the appearance of a row of cocci (*see* fig. 83). These uncoloured portions refract the light highly, and microscopically many of them have certainly the appearance of spores, though this cannot be held to be definitely proved.

The bacilli may be found wherever the growth of tubercle is going on, though in varying numbers, according to the rapidity and character of the growth. As a rule, it may be said that the more acute the tubercular process, the more numerous are the bacilli. In recently formed, rapidly growing tubercles, they are generally present in large numbers, even in the central parts which are showing signs of degeneration; whereas in chronic fibroid tubercles they may be very few in number; and in old caseous material, as a rule, their presence cannot be demonstrated. Sometimes in the nodules in which caseation is going on there can be seen in the degenerating parts bacilli which stain imperfectly, and have lost their distinct form; or only a few granular remains may be seen, some of which may be spores. This is the more likely, as caseous material has been found capable of producing tubercle on inoculation, though no tubercle bacilli could be demonstrated in it. The bacilli, as seen in the tissues, are sometimes scattered fairly uniformly, sometimes closely gathered in little clusters, and may occur partly within cells, partly lying free. Frequently in bovine tuberculosis, more rarely in the disease in the human subject, they may be seen to have a special relation to the giant-cells. In these cells the bacilli often form a sort of ring or zone towards the periphery, and are sometimes arranged in a radiate manner (*see* fig. 84). They are generally found apart from the nuclei, and the protoplasm of the giant-cell often shows a granular and partially degenerated appearance. In acute caseous catarrhal changes in the lungs, they may often be found in very large numbers in the contents of the air-cells, especially where the process

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is spreading. In some very acute forms of the disease they may sometimes be seen in parts in which no distinct tubercles have yet formed; the writer has seen this very well in the spleen in acute tuberculosis. In the sputum of phthisical patients their presence can generally be revealed with comparative ease, and for this purpose Neelsen's carbol-fuchsin method is probably the most suitable. In order to find them, one of the small yellow caseous-looking masses in the sputum ought to be selected, broken down between cover-glasses, and treated as above described (*vide* Modes of Staining). They are generally

FIG. 84.—Tubercle Bacilli in section of a cow's udder. Showing relations of bacilli to a giant-cell. × 850 diam.

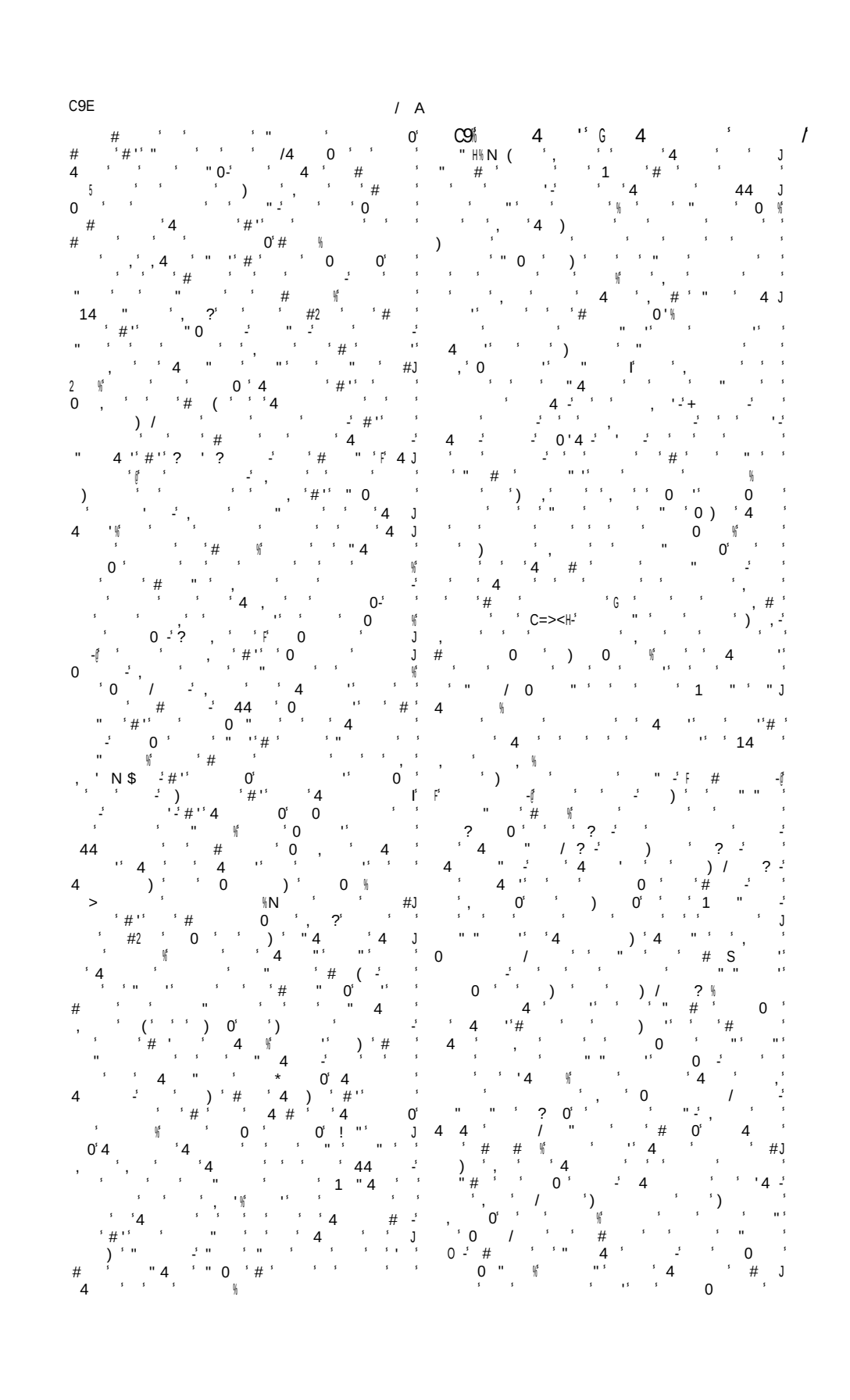
found in little groups, sometimes in very large numbers, and occasionally so closely massed together as to make the recognition of individual bacilli difficult. They may also, of course, occur singly here and there. They may also be demonstrated in the urine in cases of renal phthisis, in the dejecta in tubercular ulceration of the intestine, and in the milk of cows with tubercular udders.

Cultivation.—Koch's first attempts at cultivation on the media then in use were unsuccessful, but he ultimately succeeded on blood-serum prepared by an ingenious method. He sterilised it by heating to 55° C. on successive days—sterilisation by steam being inadmissible, on account of its coagulating the albumen, and rendering the medium opaque; and subsequently inspissated it at a temperature of 65° C. The medium thus obtained is transparent, semi-solid, and sterile. As the presence of other organisms requires to be rigorously excluded, he first employed for inoculation portions of tubercular material from animals, which of course could be obtained from them in a perfectly fresh condition. The skin of the animal having been previously purified by washing with an antiseptic, and all the scissors, knives, &c., used in the operation having been sterilised by heat, he dissected out portions of the nodules, and made inoculations on the serum. For the first few days no signs of growth were observed, but generally on the tenth to the fourteenth day the growth made its appearance. It first appears as a small whitish point, which gradually spreads on the surface of the medium, becoming more distinctly white or yellowish-white; and ultimately forms a small scale-like film of wrinkled appearance. The growth progresses slowly throughout, and after a week or two comes to a standstill. It never penetrates into the surface of the medium, and causes no liquefaction. In meat-broth growth is very imperfect, and occurs only when the liquid is in a thin layer, as the organism is strictly aërobic; but on glycerine-agar, as Nocard and Roux first pointed out (*Annal. de l'Inst. Past.* 1887, p. 19), the growth both appears at an earlier date, and is more rapid and abundant than on blood-serum. But the successive cultures tend to diminish in vitality and virulence. The young colonies on solid media, when examined with a low power, show characteristic appearances which, so far as is known, are quite peculiar to the tubercle bacillus. The margins of the growth have the appearance of wavy bundles of hair running in a sinuous manner, whilst those bundles in the central portion give the appearance of a number of laminæ intertwined. The bundles, or laminæ, are composed of bacilli arranged in a parallel manner. It was for a long time believed that the bacillus could grow only on animal media, but Pawlowsky (*Annal. de l'Inst. Past.* 1888, p. 303) has since found that growth takes place also on potatoes kept at a suitable temperature, if the tubercular material be well rubbed in, and the surface of the potato kept moist. When examined in fluids, tubercle bacilli exhibit no power of independent movement.

The cultivation of tubercle bacilli directly from *post-mortem* material, from sputum, &c., where many other organisms are present, is very difficult, on account of their slow rate of growth. But it has been effected by one or two very ingenious expedients, which it is needless to detail. Cultivations may, however, be made with comparative ease indirectly, by inoculating animals with the tubercular material, and then using some of the nodules produced for inoculation on the culture-media.

Tubercle bacilli flourish best at a temperature near that of the normal body. Koch found that on blood-serum growth took place readily between 30° and 40° C., that about 37° C. is the most suitable temperature, and that below 28° C. and above 42° C. growth does not take place. On glycerine-agar the temperature limits are rather more extended.

Relation to the disease.—That this organism is really the cause of tubercle was proved by Koch by a very extensive series of experiments on animals, by inoculation both of tubercular material containing the bacilli, and of pure cultures. His results have been



'lepra cells.' Absence of caseation was also noted as a character in which the new-growths of granulation-tissue differed from those of tubercle and syphilis.

In 1874 (*Norsk Magazin f. Lægevidenskab*, 1874, Heft 9; Virchow's *Archiv*. Band 79, p. 32) Dr. Armauer Hansen of Bergen discovered that the parts more especially affected by growths of leprosy, and particularly those in most active development, contained large numbers of bacilli. Further researches, first by Neisser in 1879, and since by many observers in all parts of the world, have established the constancy of their presence, and of their peculiar characters and relations to the diseased parts, and have confirmed the accuracy of Hansen's observations. As there has been much dispute as to their exact relations to the tissues, and as our knowledge on many points is yet very incomplete, it will be well only to state those facts which are best ascertained, most of which the

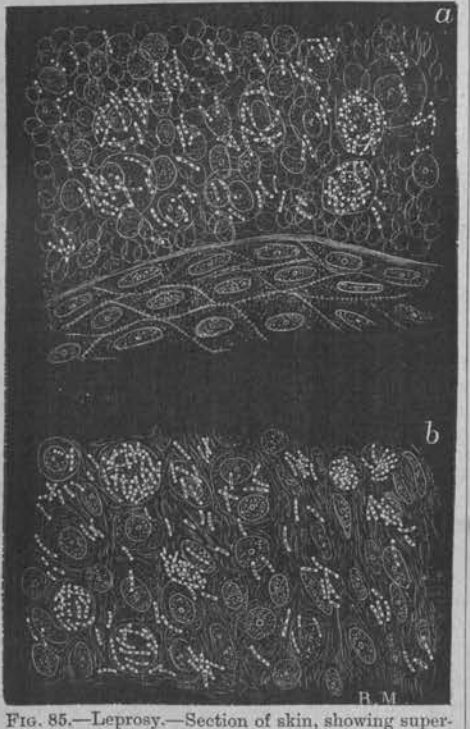


FIG. 85.—Leprosy.—Section of skin, showing superficial and deep parts of the same section. *a*. Exudation on surface of skin, showing numerous red blood-corpuscles and leucocytes, together with large cells. The bacilli are for the most part contained in these large cells. *b*. From deeper part of the same section, showing the relations of the bacilli to the cells and tissues. × 850 diam.

writer can confirm from his own observations, and to leave the disputed points for further investigation.

The *bacillus leprœ*, or *leprosy bacillus*, as seen in the tissues, very closely resembles the tubercle bacillus. It may be studied either in the juice expressed from one of the nodules (especially those in the skin), or in sections prepared and stained. In the first condition they are motionless (although some have stated that they may have a slow movement, this appears to be an error). They can be far more readily stained with ordinary aniline dyes than tubercle bacilli, and if stained in the same way as tubercle, they are rather more readily decolorised. They stain well with carbol-fuchsin, safranin, or gentian violet. Fuchsin with a contrast stain of methylene blue does well. It has been observed that some stains give a most definite appearance of bacilli. Others show a row of spore-like bodies (coccothrix), due to the fact that some parts of the bacilli are much more readily stained than the rest.[1]

The bacilli are usually straight, or very slightly curved, of nearly uniform thickness, rounded or slightly pointed at the ends. They always show the peculiar beaded or spore-like character of dots at fairly regular intervals, which have a different refraction, and different reaction to staining from the rest of the protoplasm. *See* fig. 85.

The tenacity of life of these bacilli when placed in a suitable position is very remarkable. In the numerous attempts which have been made to inoculate leprosy in animals, it has been found that even where no proliferation had, so far as could be judged, taken place, the bacilli remained in an apparently living condition in the subcutaneous tissue for several weeks or months.

These organisms are generally found in leprosy in large numbers, and have a special relation to the histological changes—*i.e.* they are present wherever the growth of the granulation-tissue is going on. A considerable amount of discussion has taken place with regard to the exact site of the bacilli in the tissues; but it is now generally admitted, as Neisser, Cornil, and Suchard described, that they are for the most part contained within the large globular 'lepra-cells.' In the leprous nodules of the skin, it can be seen that they are present in large numbers in the cells of the infiltration of the dermis and of the subcutaneous tissue, whilst the epithelium is generally quite free from them. So also in the glandular structures of the skin they are generally absent, though they may occasionally be present in the sebaceous glands, in the hair-sheaths, &c. A few may also be found lying free in the lymphatic spaces. The number of bacilli may be enormous, especially in the nodules which are chiefly cellular, each cell in the field of the microscope sometimes containing a considerable number (*see* fig. 85). In all the parts affected by the lesions the bacilli are

[1] See Neisser, *Verhandl. d. Deutsch. Dermatolog. Gesell.* Congress-Burg. 1889, and *Cent. f. Allgem. Path.* 1890, p. 166.

needle-track. The only difference observed is that it is rather more yellowish in tint, and more opaque in appearance. The rods also tend to be of greater length, and, as already stated, they differ in staining with Gram's method.

Organisms have, however, been found in other situations by various observers, which in their characters are said to be similar to the bacillus of rhinoscleroma, and some of them have been cultivated from healthy nasal secretion; and it has been held that in rhinoscleroma some of these organisms have simply passed into the tissue already diseased. Yet the invariable presence of the organism, and its special relation to the tissue-changes, are strongly in favour of its standing in causal relationship to the disease.

Unfortunately, experiments on animals are not conclusive, and different results have been obtained by different observers. Paltauf and v. Eiselsberg failed to produce any change like rhinoscleroma; whilst Pawlowsky, by injections into the anterior chamber of the eye, produced a chronic inflammatory overgrowth with large epithelioid cells, some of which contained hyaline globules such as are found in rhinoscleroma. From what we know of other diseases, it is scarcely likely that a true rhinoscleroma can be produced in animals.

Bandler has found the same organism in a chronic inflammatory thickening of the vocal cords—*chorditis vocalis inferior hypertrophica*—and has made pure cultivations from the diseased tissue; and accordingly believes that the affection is the same as rhinoscleroma.

14. **Syphilis.**—Although many observations had been made on this disease, with a view to finding characteristic micro-organisms, and such had been described by various observers at an earlier date, the work which is probably of most importance, and which has certainly attracted most attention, is that of Lustgarten, who in 1884 announced the discovery of a bacillus with special properties. He found in the affected tissues thin bacilli, generally 3·5 to 4·5 μ in length, often bent or slightly irregular, with small swellings at the extremities, and sometimes showing two to four spores in their interior. They occurred chiefly within the larger cells, especially at the periphery of the syphilitic infiltration, though some were also found lying free in the lymphatic spaces. He was able to demonstrate these organisms in all of sixteen cases which he examined, using a special method as follows: The sections were stained for twenty-four to forty-eight hours in an aniline-water solution of gentian violet; and after being washed in alcohol, were placed for ten seconds in a 1·5 per cent. solution of permanganate of potassium. They were then treated with sulphurous acid, which removes the brown precipitate which has formed and decolorises the sections; washed in water; dehydrated, and mounted. Tubercle and leprosy bacilli can be coloured in the same way; but, unlike these, the 'syphilis bacilli' are easily decolorised by mineral acids. Subsequent observations would appear to show that these organisms are not always present in the syphilitic lesions, and several competent observers have altogether failed to find them. Moreover, it has been asserted that a similar organism may be normally present on the surface of the genital organs (the *smegma bacillus* of Alvarez and Tafel), and that in syphilis it enters the affected tissues secondarily. This, however, would not explain its presence in the lesions in the internal organs in syphilis. Since the publication of Lustgarten's work, other organisms, supposed to be characteristic, have been described by various observers as being present in the tissues, and even in the blood, in syphilis. The whole question is at present in a very doubtful state, and we cannot say that any particular organism is even probably the cause of the disease.

GROUP IV. — *Diseases associated with Spirilla.*

15. **Cholera, Asiatic.**—Although many attempts had been made to discover the cause of cholera, and various fungoid and allied organisms had been found in the discharges, and had been supposed to be the specific agent, none had any sufficient scientific support until the discoveries of Koch in 1884. But it cannot be doubted that antecedent observations, erroneous though they may have been, paved the way for the acceptance of the view that cholera may be due to a micro-organism.

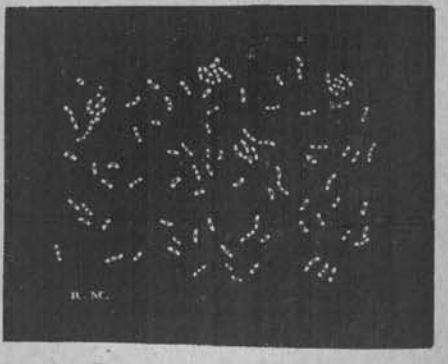


FIG. 86.—Koch's 'Comma-Bacillus,' or Spirillum of Asiatic Cholera—From a dried culture; stained with fuchsin. From the Berlin Health Laboratory. × 900 diam.

It might be well to state at the outset that, although the observations of Koch may be regarded as practically beyond dispute, and

although the organism discovered by him affords in its reactions a striking explanation of many of the phenomena of cholera, yet we lack absolute scientific proof of its causal relation to the disease. Enough is known, however, to make its provisional inclusion justifiable. Moreover, Koch's results have been confirmed by the vast majority of competent observers in all parts of the world.

The 'comma bacillus' of Koch, or 'Spirillum choleræ Asiaticæ,' is a very minute organism, each cell being about 1·5 to 2 μ in length, and ·5 to ·6 μ in thickness, curved in varying degree, and therefore resembling a comma. Each cell is flagellated at one or both ends, commonly only at one end, the flagella being either single or double, from one to five times the length of the cell, and not more than ·05 μ in thickness. As in other spirilla, the flagella may be present only at some periods of life; and we may find the cells when they are grown under various conditions, in pairs, S-shaped, or in longer filaments of corkscrew form, and even as straight rods. (This will be best understood from a comparison with the drawing of spirillum undula, fig. 69.)

The cells are actively motile, especially in warm temperatures. When stained, the individual cells may show darker parts at the ends or centre, suggesting possible spore-formation. But although much attention has been devoted to this question, no spores have yet been proved to exist.

The microscopical characters are seen in the accompanying figures, one of which (fig. 86) is drawn from a specimen stained with fuchsin, the other (fig. 87) from one stained by Löffler's method for showing flagella.

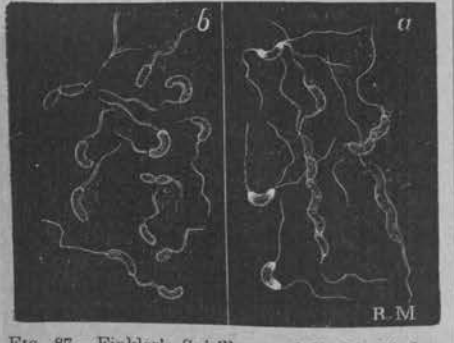


FIG. 87.—Finkler's Spirillum and Koch's Cholera Spirillum, both prepared in the same manner, stained by Löffler's method, to show flagella; and placed side by side for comparison.—*a*. Finkler's Spirillum. From a culture made in the Pathological Laboratory, Univ. Edin. *b*. Koch's Cholera Spirillum. From a specimen from the Berlin Health Laboratory. × 2,000 diam.

Side by side with the latter is a drawing from a cultivation of Finkler's comma bacillus, stained by the same method. The relations of Finkler's bacillus or spirillum will be subsequently referred to.

To stain the spirillum, after drying the intestinal contents on a cover-slip, a watery solution of fuchsin may be used, best with heating for about ten minutes. But Löffler's method gives far better results, though it is much more tedious and uncertain. Specimens stained in this way usually appear larger than when simply stained. For partial staining, a very dilute solution of methyl violet may be mixed with the intestinal contents on the slide.

Sections of the intestine may be stained for twenty-four hours in fuchsin or alkaline methylene-blue solution.

Growth and Cultivation of the Spirillum. These organisms grow best in alkaline media, and with free access of oxygen; indeed, it is said that some of the movements appear to be actively directed to the search for oxygen when a 'hanging drop' is studied. But they must be capable of growth with a deficient supply of free oxygen, as in the intestine, deriving it from the blood and lymph, or from compounds which contain it.

The presence of acids is generally prejudicial to their growth, yet they grow on potatoes of which the reaction is slightly acid.

For active growth a temperature of 30° to 40° C. (85° to 104° F.) is best suited, and growth is arrested below 15° C. or above 42° C. Growth also ceases in an atmosphere of H or CO_2, but revives on readmission of oxygen. A temperature of −10° C., or vacuum, does not destroy the spirilla; but drying for two to three hours, or a temperature over 50° C., soon kills them. They grow readily in meat-broth, even when exceedingly dilute, in milk—producing little or no perceptible change in it, on blood-serum, nutrient gelatine or agar, and on potatoes.

The growth on nutrient gelatine and on potatoes is especially employed for diagnostic purposes.

In gelatine-plate-cultivations, made in the manner already described, minute whitish points appear, and around them the gelatine liquefies, the minute colony, not larger than 1 mm. in diameter, sinking into a funnel-shaped depression. By the end of the second or third day (if the plate is kept at about 20° C.) it is covered with these small funnel- or bubble-shaped depressions. The liquefaction spreads peripherally, and the entire surface becomes liquefied, the rapidity of course depending on the number of points of growth.

The appearances on examining the plate microscopically in the usual way, with a low power, are also peculiar. The individual colonies are very irregular in shape, and as they enlarge they appear highly granular, resembling, as Koch remarked, a mass of particles of ground glass, and having a peculiar glistening appearance, the colour being white or faintly yellowish. As lique-

Group V.—Not coming into any of the previous classes.

17. **Anthrax.**—The Bacillus anthracis is one of the best known and most fully investigated of all pathogenic bacteria, and was the first to be conclusively proved to be the cause of a definite disease in man, and in some of the lower animals. It was first observed in the blood of animals affected with the disease by Pollender in 1849, and was afterwards the subject of important investigations by Delafond, Davaine, Brauell, Koch, and later by Pasteur. By the experiments of these workers its causal relation to the disease had been almost conclusively proved, but the final proof was given by Koch in 1876. He was the first to succeed in obtaining pure cultivations of the bacillus outside the body, and was thus able to test the effects of its inoculation on animals without risk of fallacy. Owing to its comparatively large size, this organism has been the subject of much study, which has yielded valuable information on the morphology of bacteria, the origin and mode of formation of spores, as well as their vital properties and powers of resistance. Furthermore, discoveries regarding modification of its virulence, and the possibility of preventive inoculation, have proved of great value in relation to the whole subject of acquired immunity, and have been of much practical utility. It also serves as an excellent example of a micro-organism causing rapidly fatal results by its multiplication in the blood throughout the body.

The Bacillus anthracis (*bactéridie du charbon*; *Milzbrandbacillus*), as seen in the blood of an animal affected with the disease, occurs in the form of comparatively large rods, whose thickness is about 1·5 μ, and whose length is generally about the diameter of a

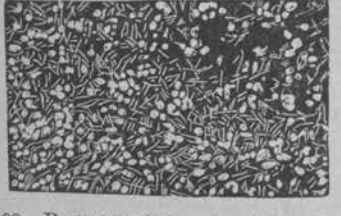


Fig. 88.—Part of the Spleen of a Guinea-pig which died of anthrax, showing the relative proportion of bacilli and leucocytes. × 100 diam. From a photomicrograph.

red corpuscle, though both shorter and much longer forms are seen. The rods may be present in enormous numbers, sometimes appearing to equal the red corpuscles in number. In the blood and in the spleen the rods occur singly, or two or three may be joined end to end, but long chains are not usually found. In the pleural exudate and in similar fluids, as well as in cultivations outside the body, the organism grows into long filaments, which may be shown to be made up of a large number of individual bacilli. The rods have slightly rounded or nearly square extremities, and their protoplasm has a homogeneous or slightly granular appearance, but spores are not usually found in the bacilli within the living body. When the organism is grown outside the body in a suitable soil, at a sufficiently high temperature (not below 18° C.) and in the presence of oxygen, spore-formation occurs, which in its chief features agrees with what has previously been described under 'Spore-formation.' The various appearances are well seen in the accompanying woodcut (fig. 89).

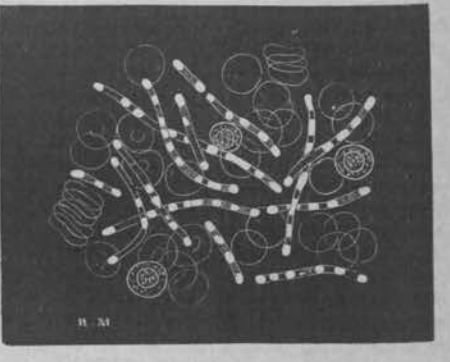
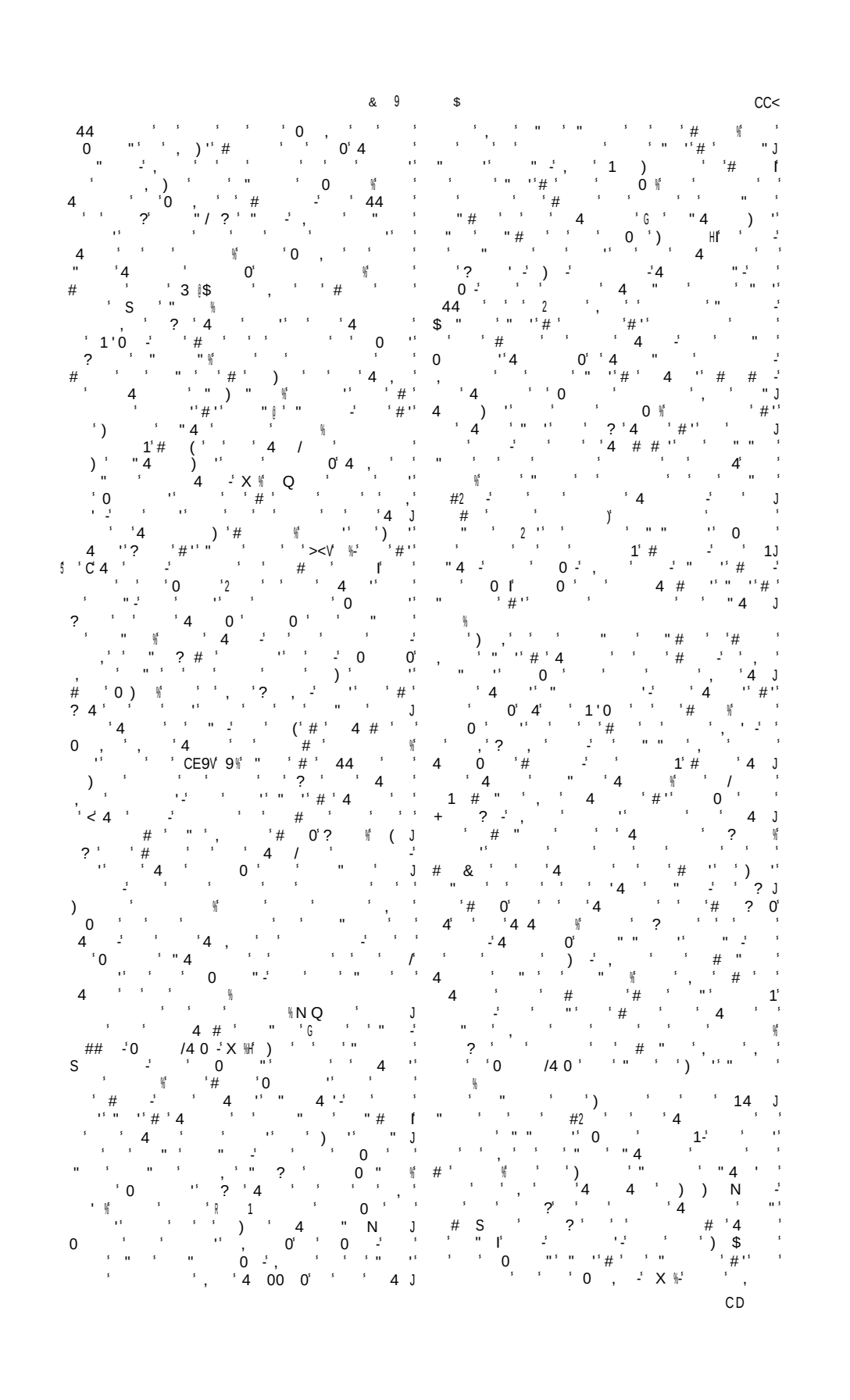
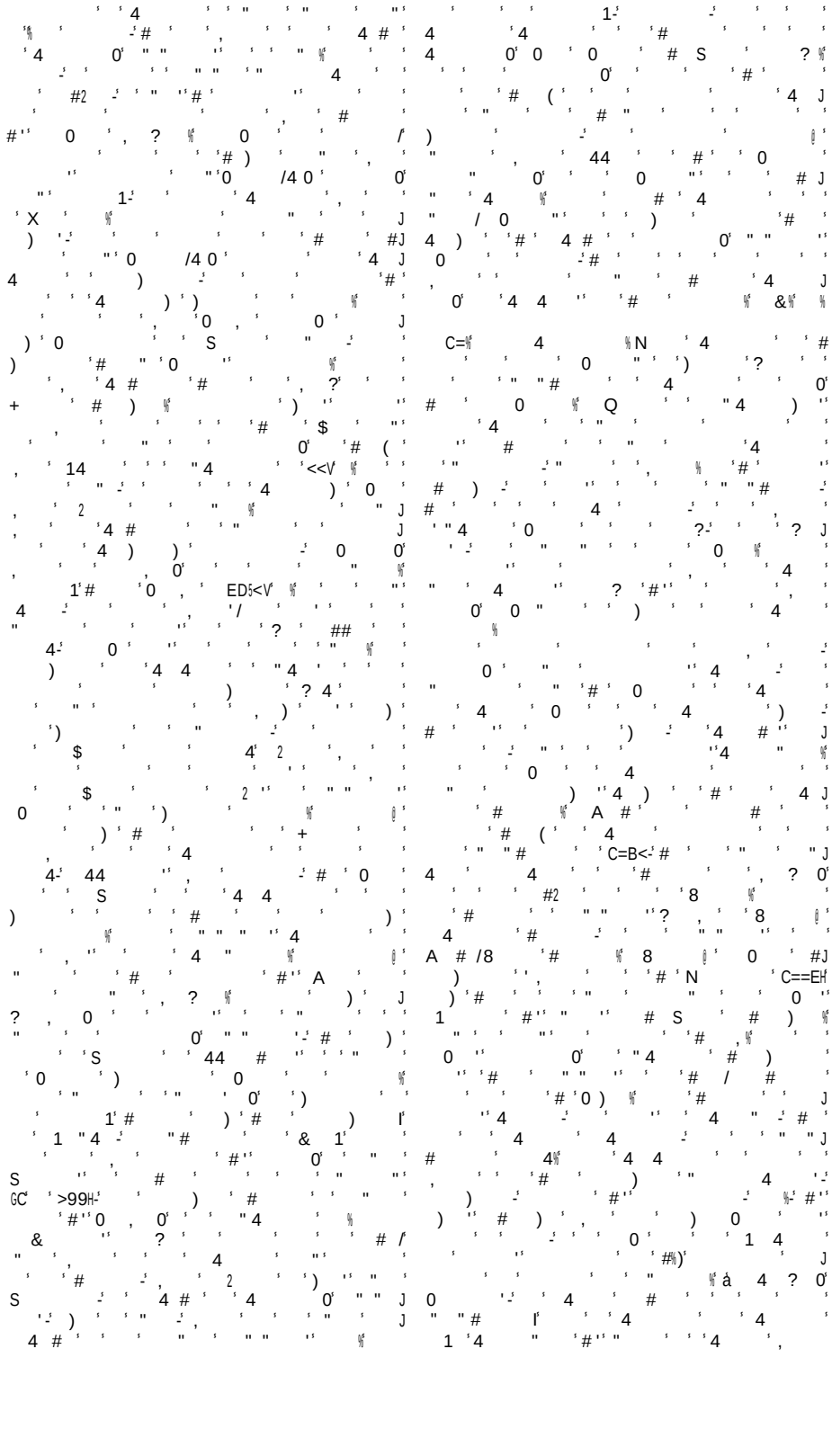


Fig. 89.—Bacillus Anthracis in a Blood-vessel in the Heart of a Cow. × 950 diam.

Cultivation, &c.—The anthrax bacillus can readily be cultivated outside the body on all the ordinary media. It grows at ordinary temperatures, but much better about 35° C., the limits of growth being generally given at 12-45° C. On certain media its growth has a characteristic appearance.

In puncture-cultivations in peptone-gelatine the growth appears along the needle-track as a somewhat whitish line from which fine lateral offshoots spread out horizontally in the medium, these also in their turn giving off lines of growth, so as to produce an appearance which has been compared to bunches of fine bristles. The lateral stems are longest near the surface of the gelatine. Later, liquefaction begins at the surface and spreads downwards, so that the characteristic features are lost, and the growth appears as a white flocculent mass at the junction of the fluid and solid portions. In plate-cultivations minute white colonies appear, which, on reaching the surface of the gelatine, cause a little area of liquefaction around them. If these superficial colonies are examined with a low-power lens, the periphery is found to have an appearance like masses of curly locks of hair, the centre of the colony being denser and of a slightly greenish tint. The





is there generated and absorbed into the system.

At first the bacilli are found in small numbers upon and in the superficial layers of the epithelium of the mucous membrane, especially where excoriated; and as the false membrane is formed they multiply, especially in its older and therefore more superficial parts. (That the part in which it is found may not *always* be actually the most superficial is due to the fact that in some positions layers of fibrinous exudation may be superposed at a later period, though this is not the common mode of occurrence. A detailed account of the various modes of formation of the false membrane would here be out of place.) Where the epithelium has been entirely detached, some bacilli may be found penetrating it, especially in those parts infiltrated with serum or sero-fibrinous exudation. But, with rare exceptions, they do not appear to penetrate more deeply, or to become diffused throughout the organism.

In those parts where the diphtheria bacilli are found they may be scattered, or in lines or patches, or, not uncommonly, in spheroidal

FIG. 90.—Diphtheria.—*a*. Part of false membrane from a case of diphtheria, containing both streptococci and bacilli. *b*. Streptococci; *c*. Bacilli, viewed separately. × 950 diam.

masses, which may, if the preparation is defectively stained or insufficiently magnified, be readily mistaken for masses of micrococci (*see* fig. 90).

The diphtheria bacillus is minute, of very variable length, the rods not usually exceeding 6 to 8 μ in length, the individual elements 1·5 to 2·5 μ.[1] Both in the fresh condition and in sections it may be straight or slightly curved, often somewhat swollen, and showing either at the ends or centre of the rods more deeply stained portions, the relations of which to spores will be discussed later.

More important are the facts as to the cultivation and pathogenic reactions of the bacillus.

Cultivation.—Löffler first succeeded in obtaining pure cultures of the diphtheria bacillus on a mixture of serum and gelatinised meat-infusion. His medium is composed of three parts of calf or sheep blood-serum mixed with one part of neutral gelatinised veal-broth, to which have been added 1 per cent. of peptone, 1 per cent. of grape sugar, and ·5 per cent. NaCl. It can also be grown on blood-serum alone, on glycerine-agar, and in slightly alkaline meat-broth (veal-broth to be preferred).

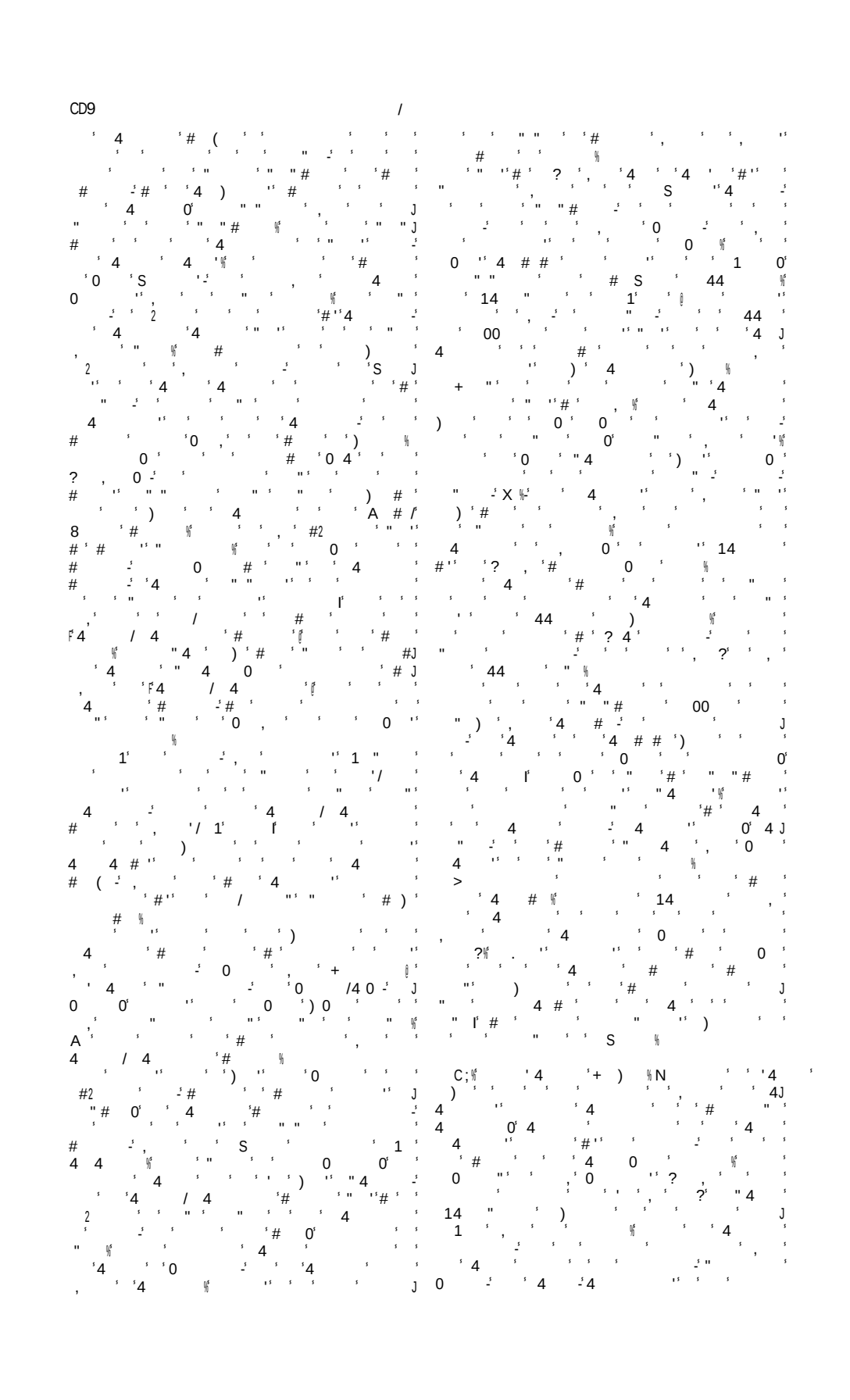
Growth proceeds almost solely above a temperature of 20° C., and well at 37° C. (roughly speaking, 70° to 99° F.) A moist temperature of 60° C. kills diphtheria bacilli, whether in the cultivations or false membranes; but when dried they may resist a temperature of 98° C. for nearly an hour. When grown on Löffler's serum they form greyish-white colonies, which extend rapidly on the surface, and become visible to the naked eye in twenty-four to thirty-six hours. It is found that the growth of the first cultivation from false membrane is slower than that of the subsequent generations, probably owing to the more complete acclimatisation.

On agar the growth has a brownish colour, and the edges are more irregular. In broth the bacilli form small whitish clumps, which fall to the bottom or adhere to the sides of the vessel. They can also be readily grown in milk. Liquefaction of semi-solid media is never produced.

The diphtheria bacillus is one which grows best in the presence of oxygen, although in liquids it appears to be capable of some growth in the absence of free oxygen ('capably anaërobic').

The vitality of the bacilli appears to be very great. It has been already mentioned that in fluids they are readily killed by a temperature of 60° C. But at ordinary temperatures their duration of life is remarkable, and still more their power of resistance to drying, which is commonly soon fatal to spore-free bacilli.

[1] In this we have an illustration of the great variety of statements by different observers, due to modes of preparation and examination. Löffler said they were about the length of tubercle bacilli, but twice as thick. Others say: average 6 μ long, ·16 μ diameter; Zarniko, 1·5 to 2·5 μ long, ·3 μ broad. The latter is approximately correct for the fresh cultivated bacilli, but in hardened and mounted specimens the diameter appears much smaller.



stages of the disease, render its provisional inclusion amongst pathogenic bacteria justifiable. It is true that the entrance of bacteria into diseased parts of the intestine is easy, and that the characters which this bacillus presents may be proved later to be not distinctive; but the early and special association with the diseased parts, and the absence of other common bacteria at the same period, add weight to its claims.

The first definite discovery was announced by Eberth in 1880 (Virchow's *Arch.* 83, p. 486); and the more accurate study and cultivation of it by Gaffky (*Mitth. a. d. K. Gesundheitsamte*, ii.) in 1884. Their work has to a large extent been subsequently confirmed by numerous observers.

Site.—The typhoid bacillus is found in the swollen Peyer's patches and solitary glands during the early stages of the fever, and also in the mesenteric glands, spleen, and liver. It is usually in colonies or clusters, formed of bacilli closely massed together (but the colonies widely scattered), and around them there is active proliferation and degeneration of the tissue-elements. The bacilli are usually short, somewhat thick, with slightly rounded ends, measuring about ·4 to ·6 μ in diameter, and 2 to 6 μ in length. In some situations their length may be greater. They frequently show spore-like bodies at the ends and centre, whose relations have been discussed above (*see* Diphtheria). They may be brought into view by various aniline dyes, especially by methylene blue, but often require special methods and careful search. They are usually decolorised by Gram's

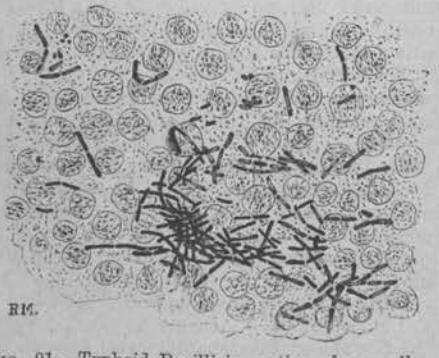


FIG. 91.—Typhoid Bacilli in section of a swollen Peyer's patch. Showing the usual appearance in stained sections. × 950.

method, unless the sections have been previously treated with corrosive-sublimate solution: even then they may be difficult to stain. As the disease advances, they appear to diminish in number, or are much more difficult to detect. Their presence has also been demonstrated in the dejecta of typhoid patients (Pfeiffer).

Gaffky succeeded in cultivating typhoid bacilli on nutrient jelly. They appear as somewhat rounded colonies on the surface of the jelly, which coalesce and spread upon the surface, forming a thin layer which acquires a slightly brownish tinge. They do not liquefy the jelly. In puncture-cultivations growth appears as a whitish line along the needle-track, but spreads specially on the surface as a flat whitish layer with a shining appearance, which may reach the wall of the test-tube. From the mode of growth they are evidently highly aërobic, but are said also to be capably

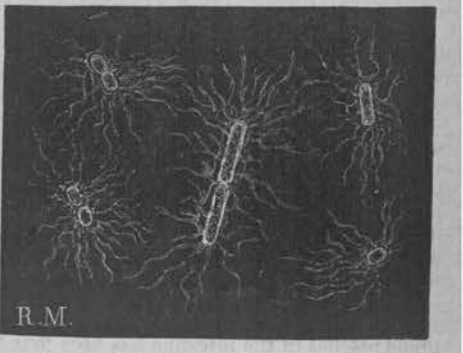


FIG. 92.—Typhoid Bacilli.—Stained to show cilia. × 2,000 diam. From a specimen prepared in the Berlin Health Laboratory.

anaërobic. In fluids they grow freely, as in broth or milk, causing but little change in the latter. Some growth occurs even in water. They are found to be motile when examined in fluids, and show a peculiar wavy or serpent-like motion, which is seen best in the longer threads. When grown upon potatoes they produce a delicate transparent layer, which is almost invisible if the potatoes have an acid reaction, slightly yellowish or grey if alkaline. The surface becomes covered in about two days at a warm temperature (38° C.), in three to four days at ordinary temperature. Longer filaments are formed in cultures than in the tissues.

A recent discovery of considerable importance is that of the peculiar characters of the cilia of typhoid bacilli, seen, by means of Löffler's method, best in young cultivations (six to eight hours) on serum. Each bacillus appears to be surrounded by a hyaline sheath, from which a large number of irregularly arranged cilia run outwards in all directions, most being lateral. Their appearance is well seen in fig. 92. This character was at first believed to be unique, but some other bacilli have since been found to possess cilia arranged in the same way. Besides, we cannot with our present means determine the constant presence of these cilia under all conditions in fluids or in sections, and their value as a diagnostic aid would be limited by this fact, even if they were peculiar to this bacillus. Nor are any of the other

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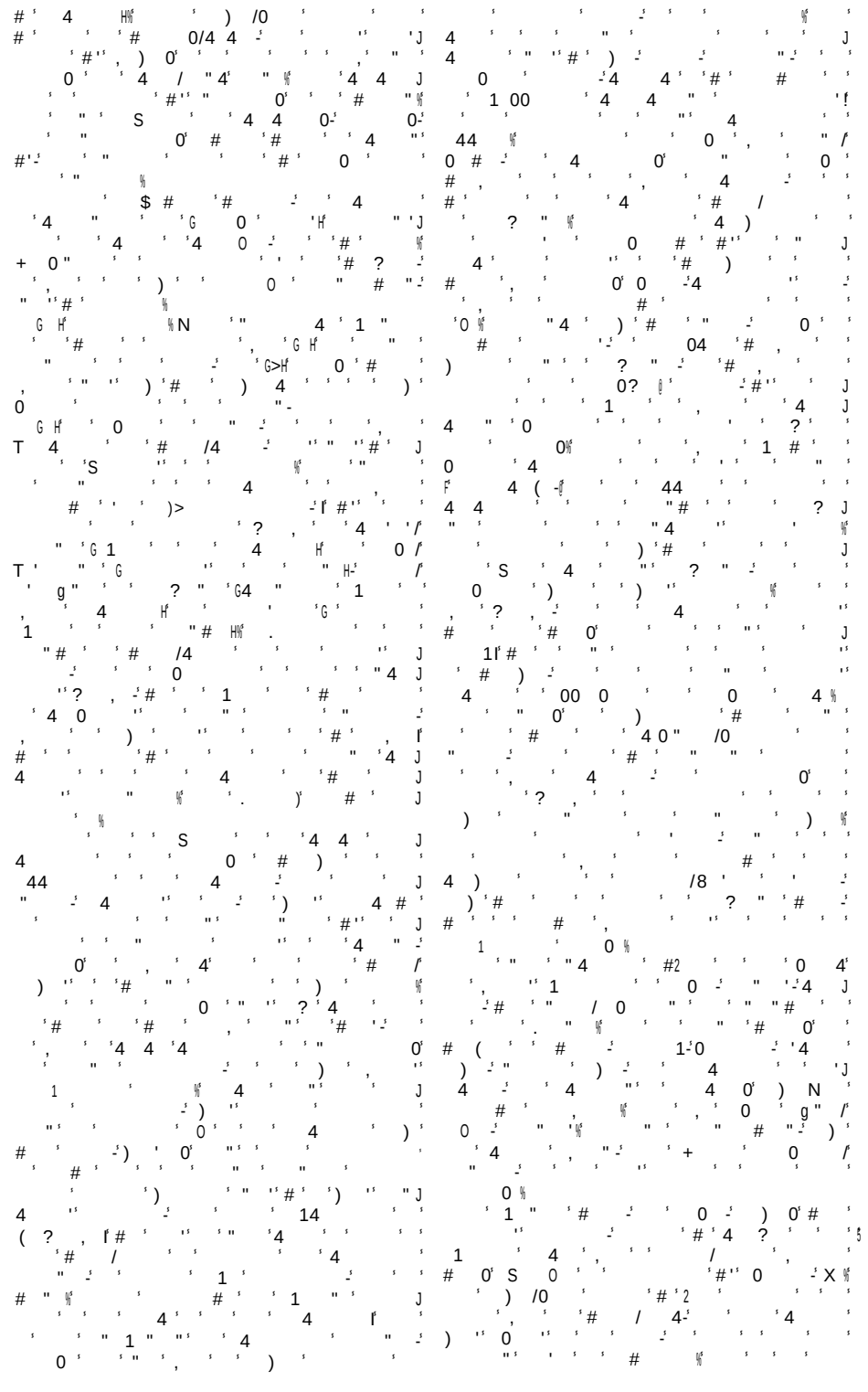
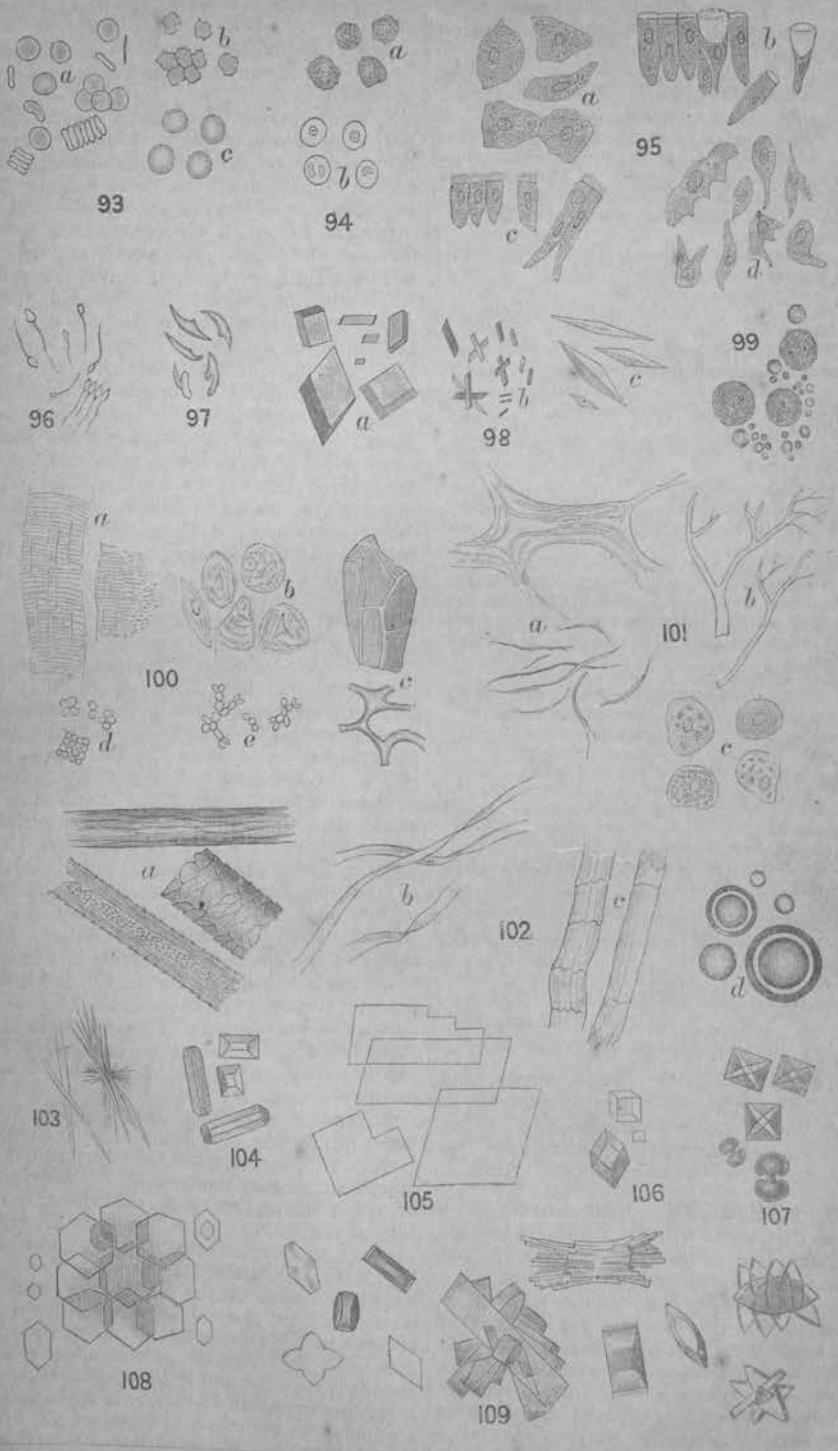
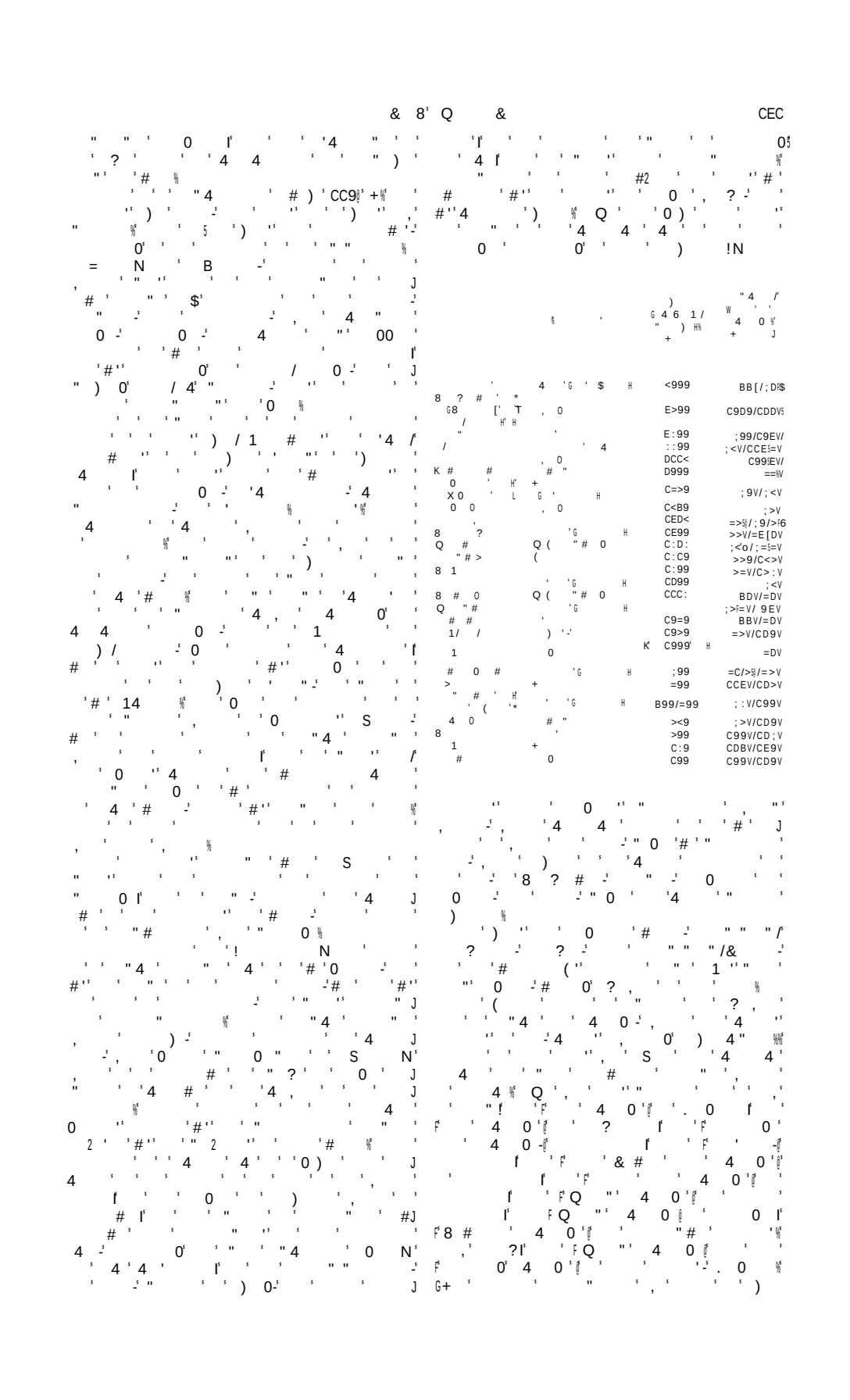




Drawings illustrating Common Objects seen with the Microscope in Medicine.



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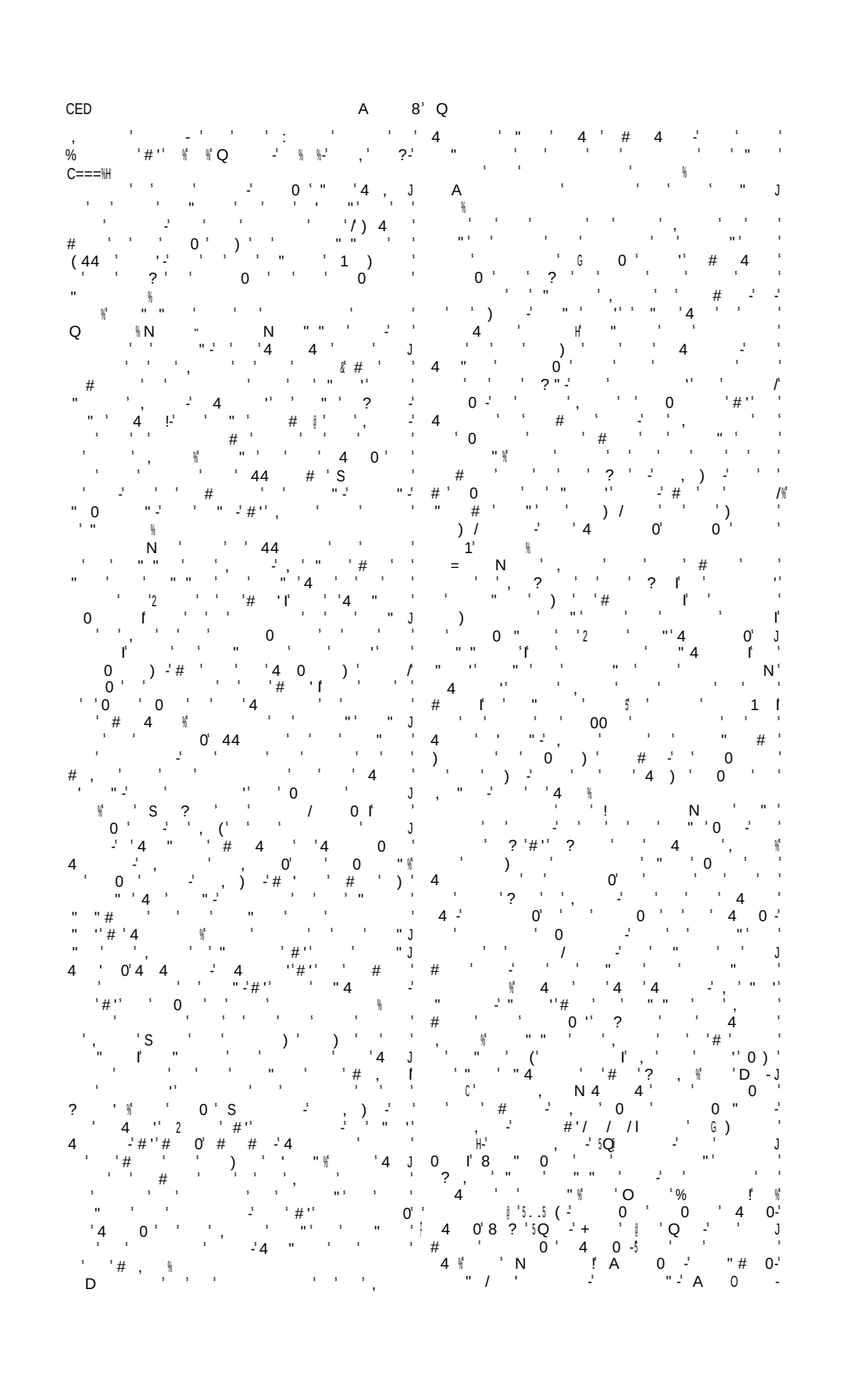

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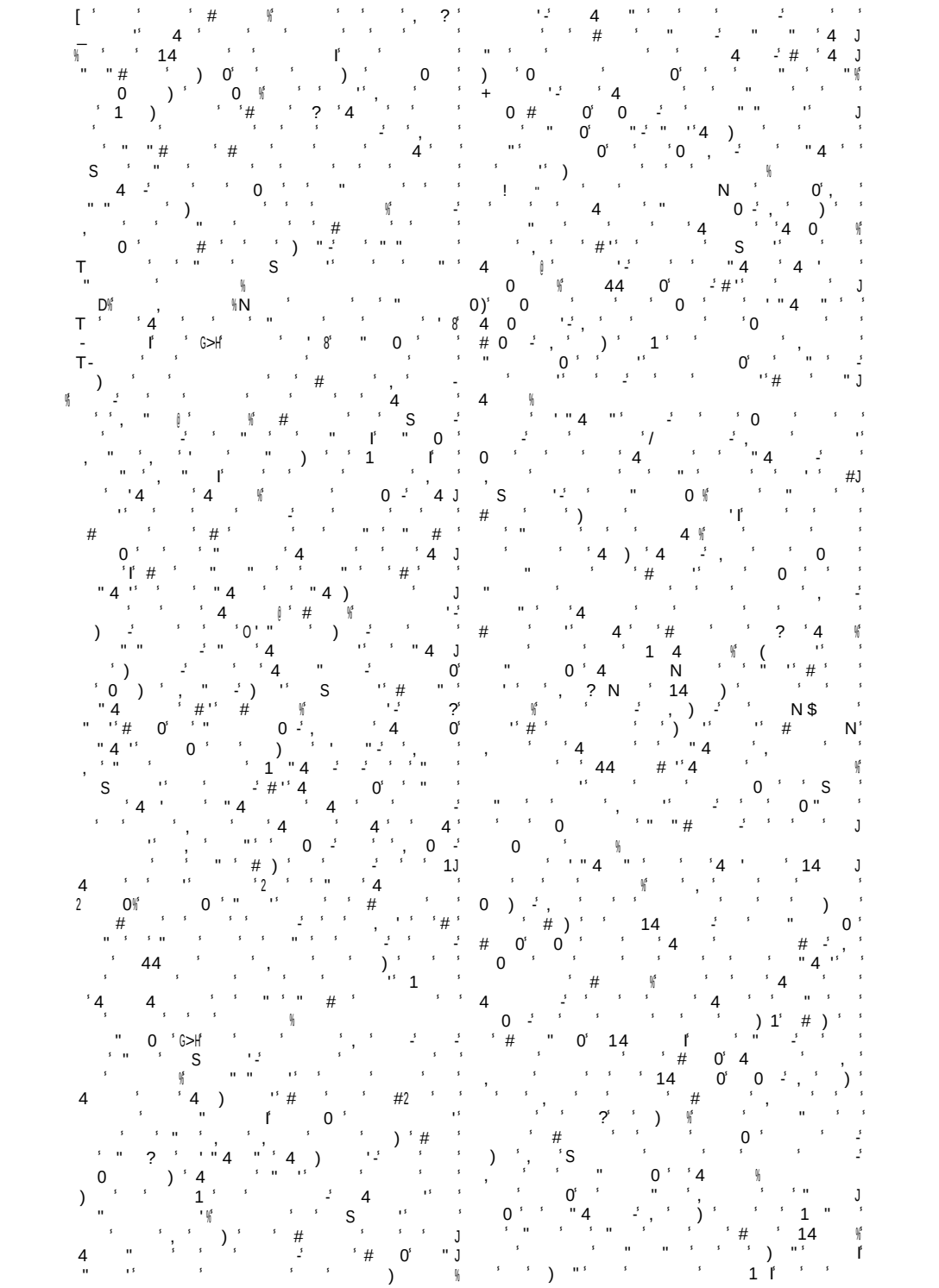

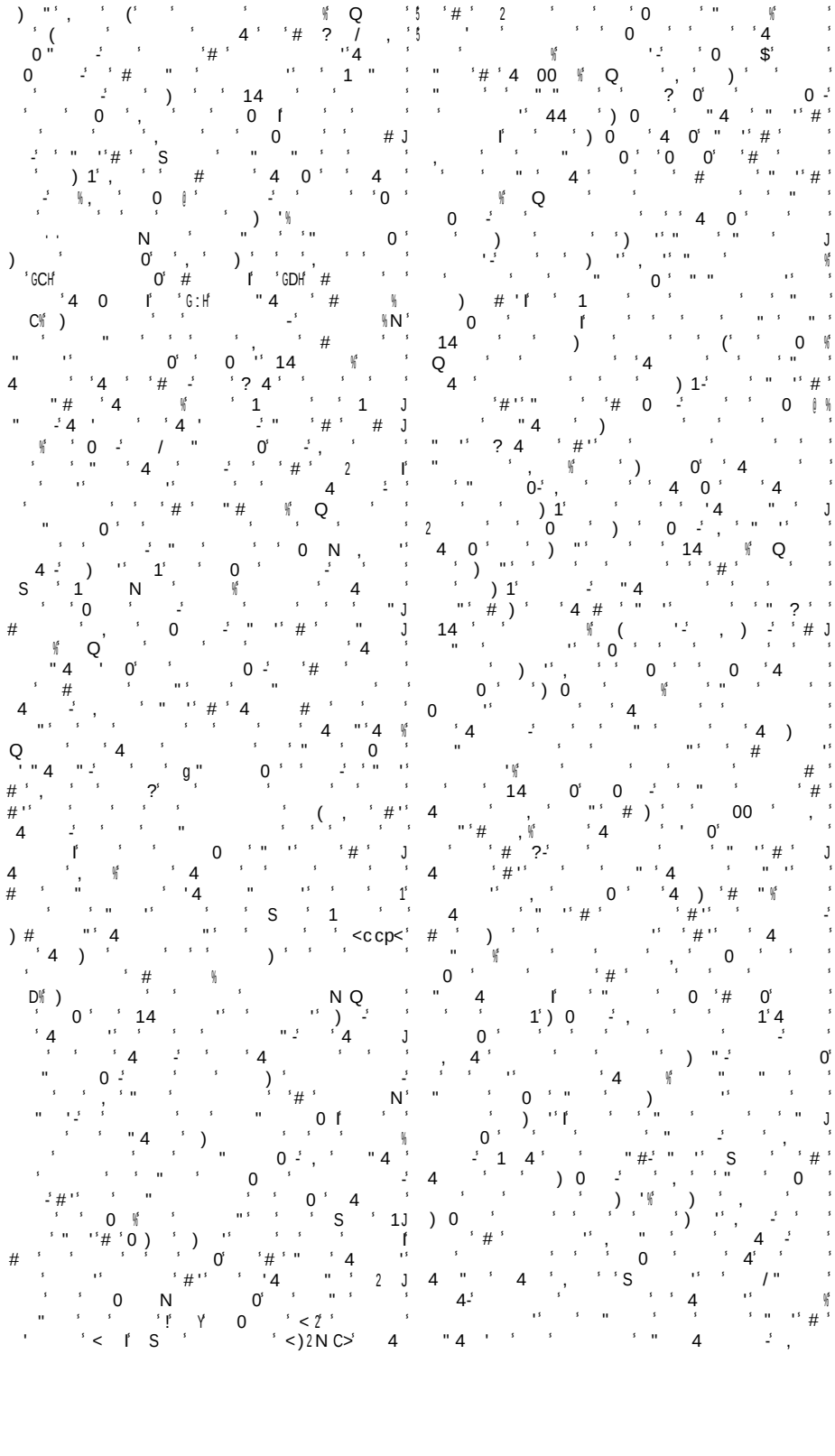

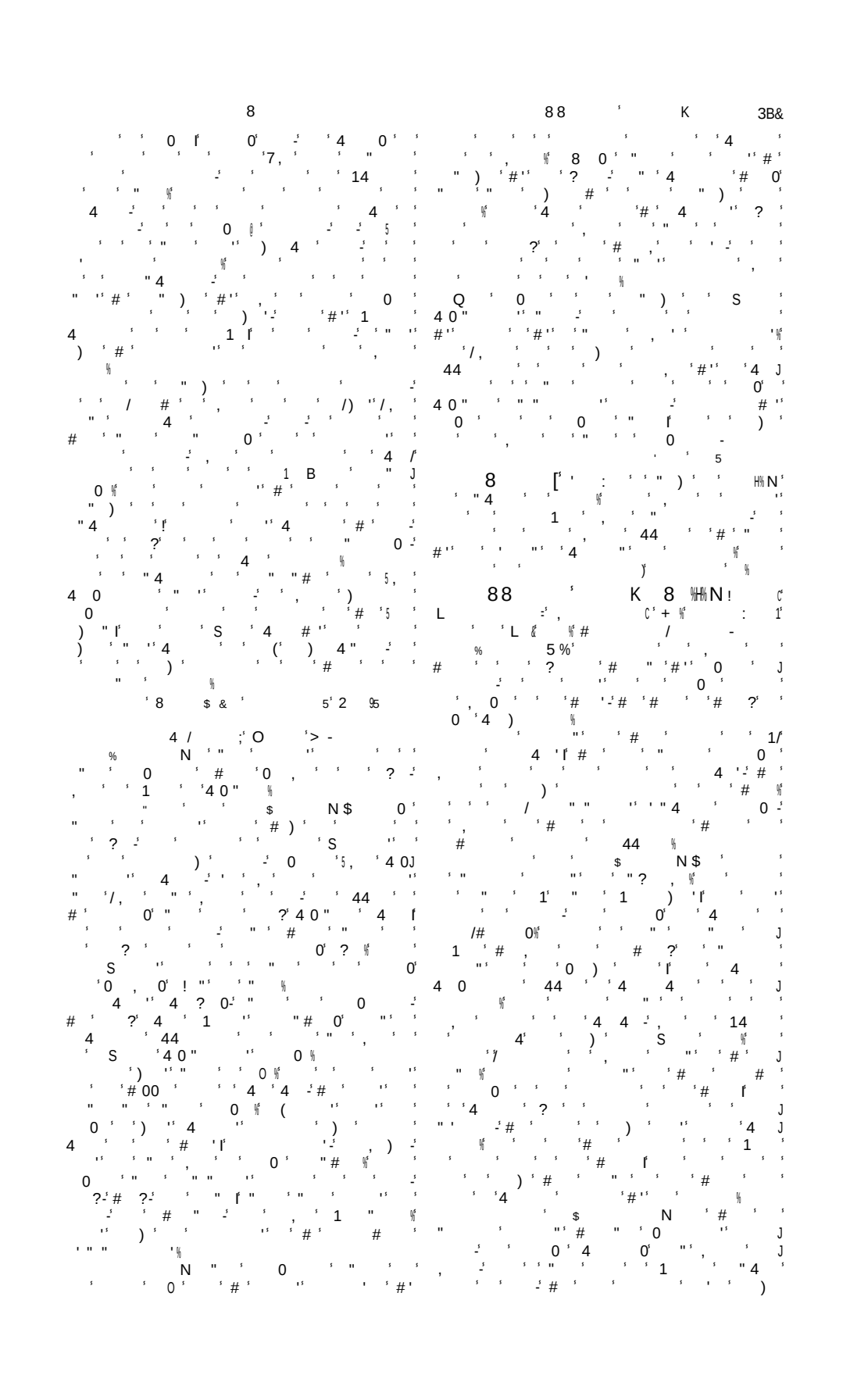

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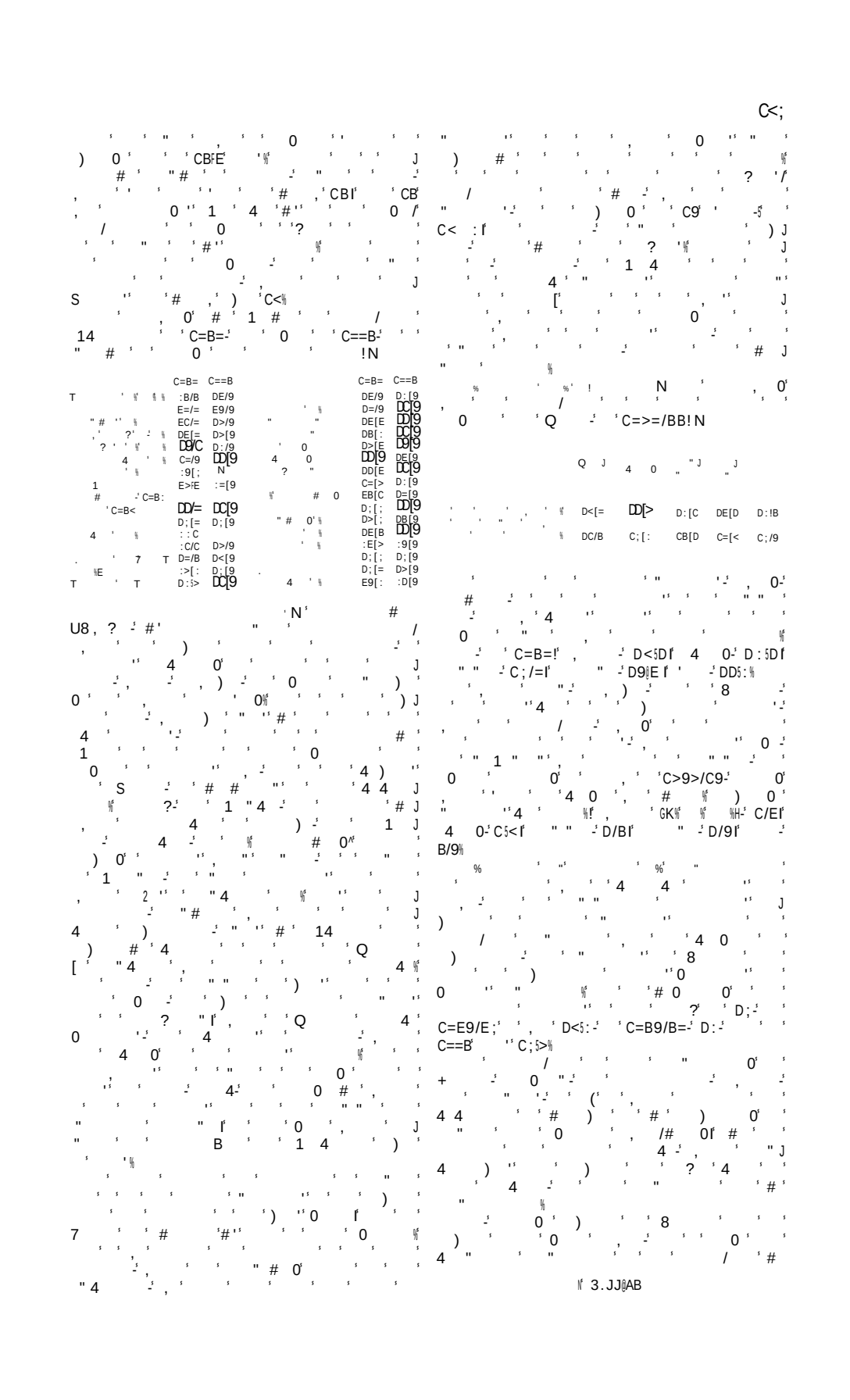

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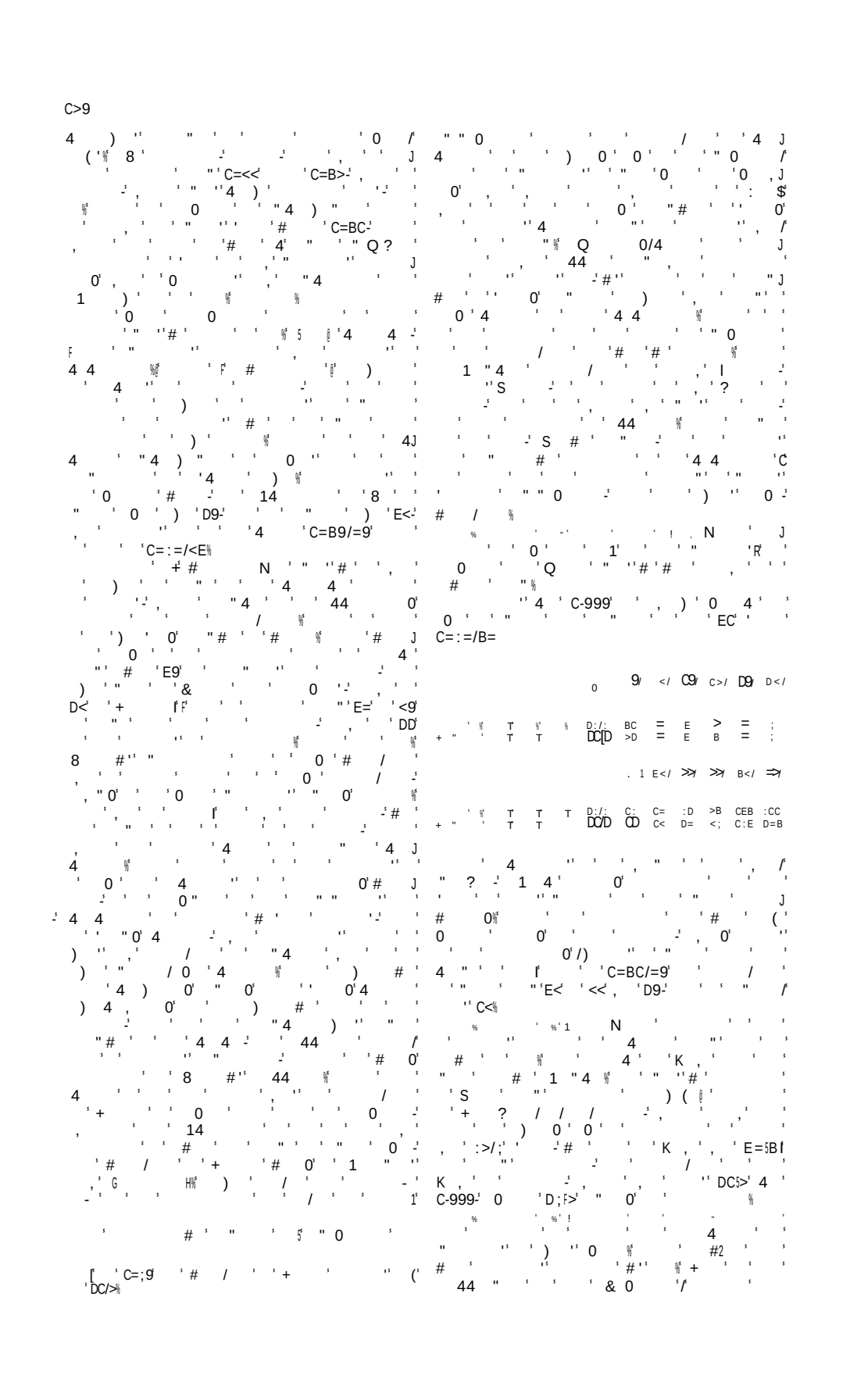

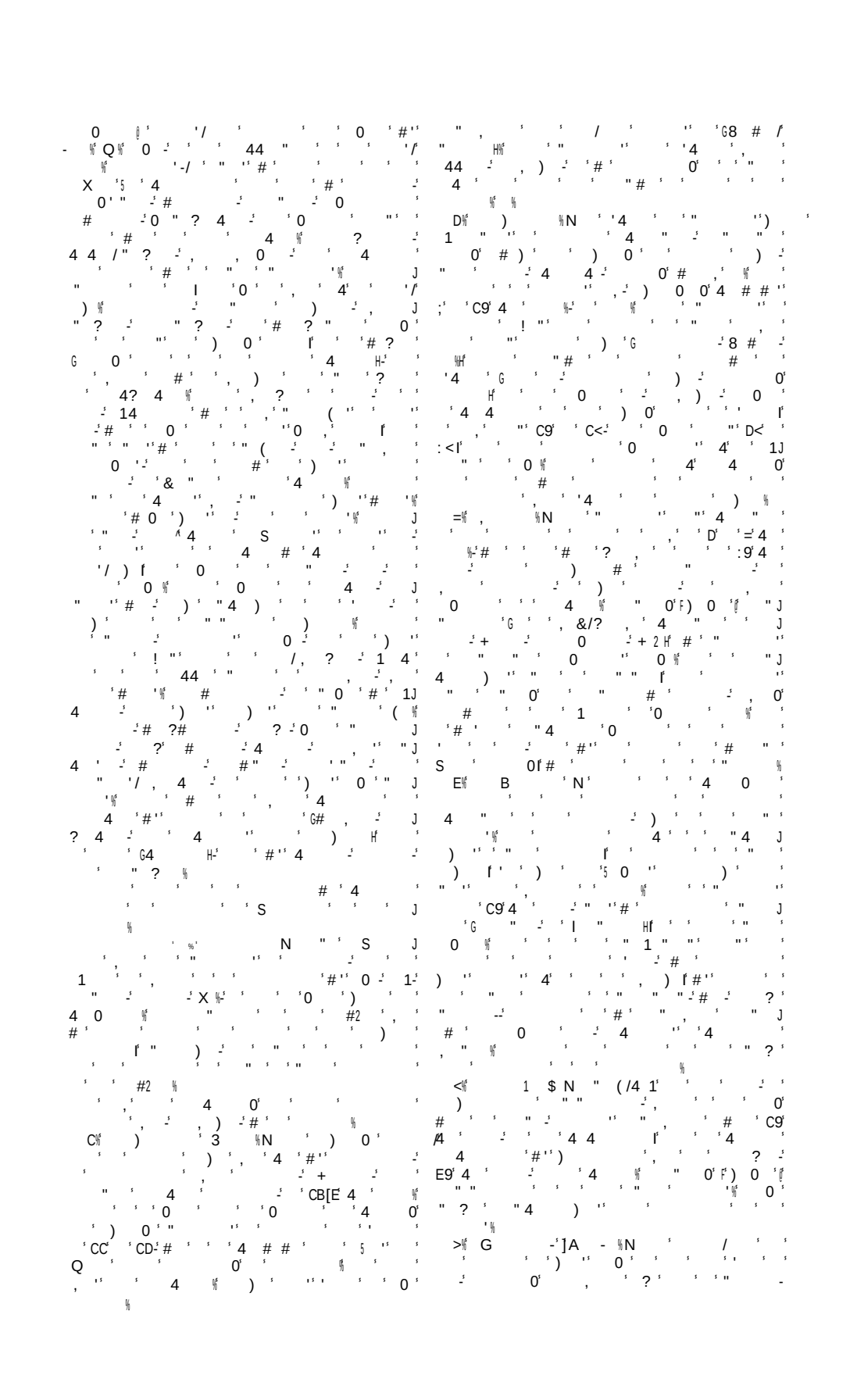

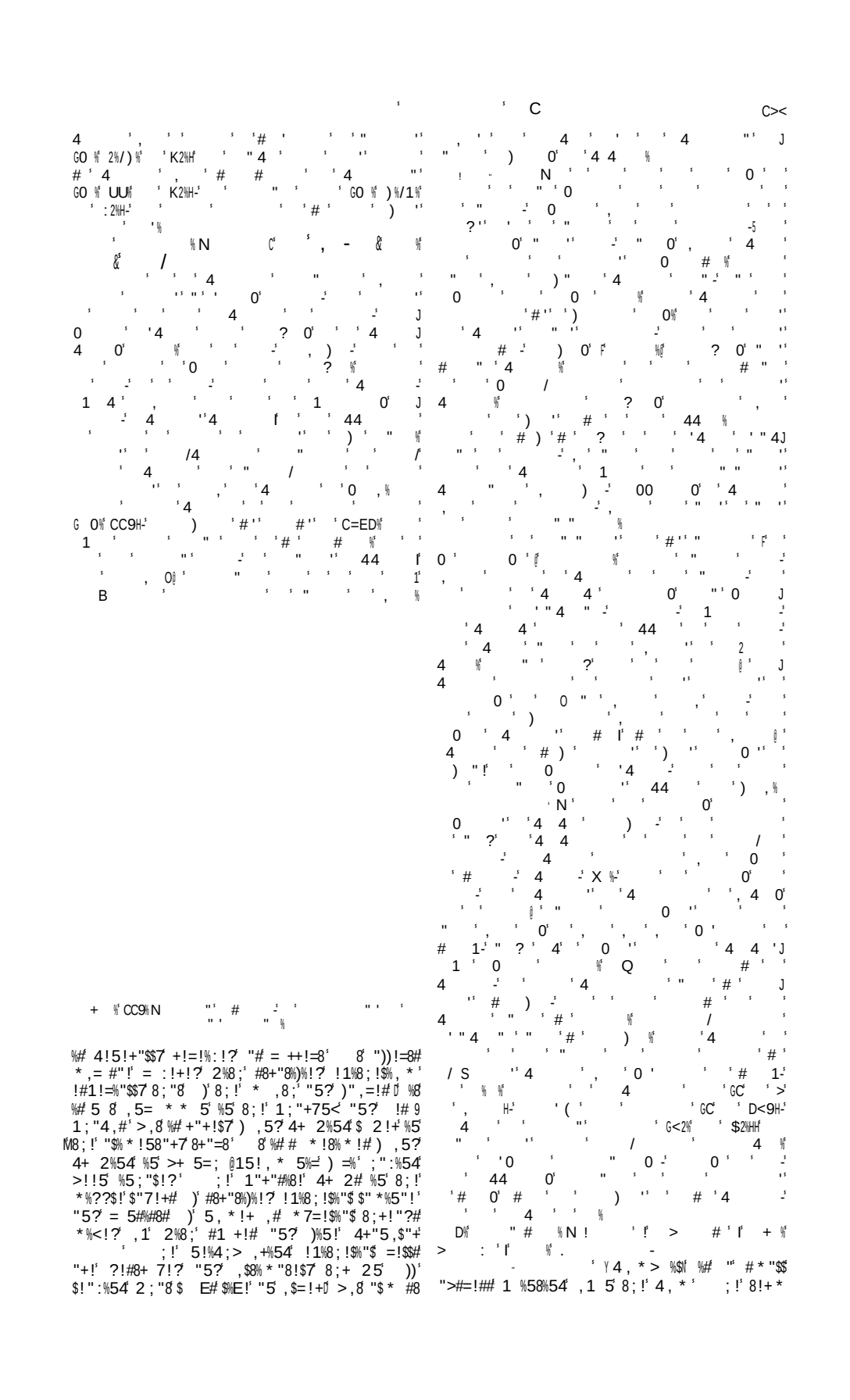

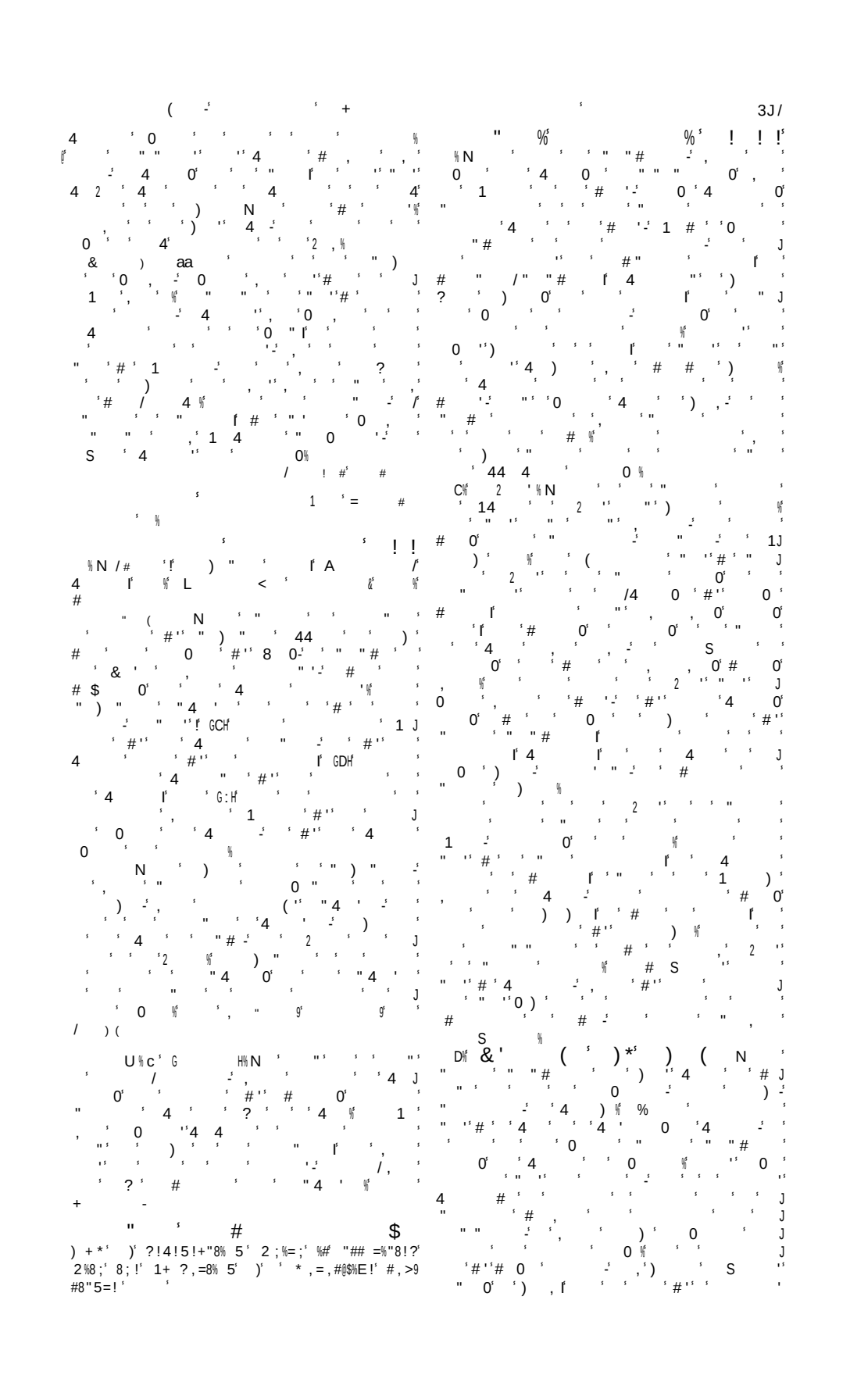

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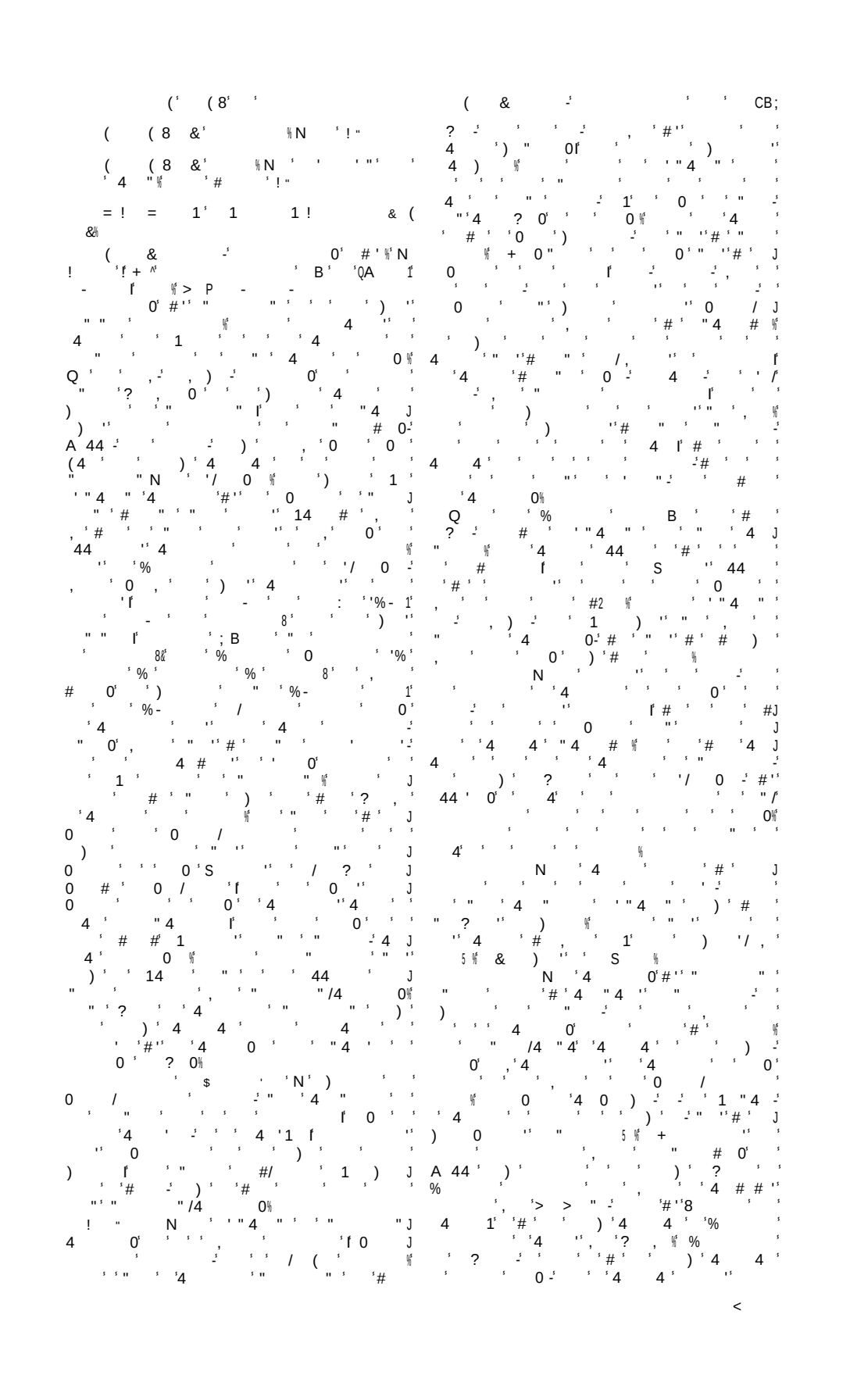

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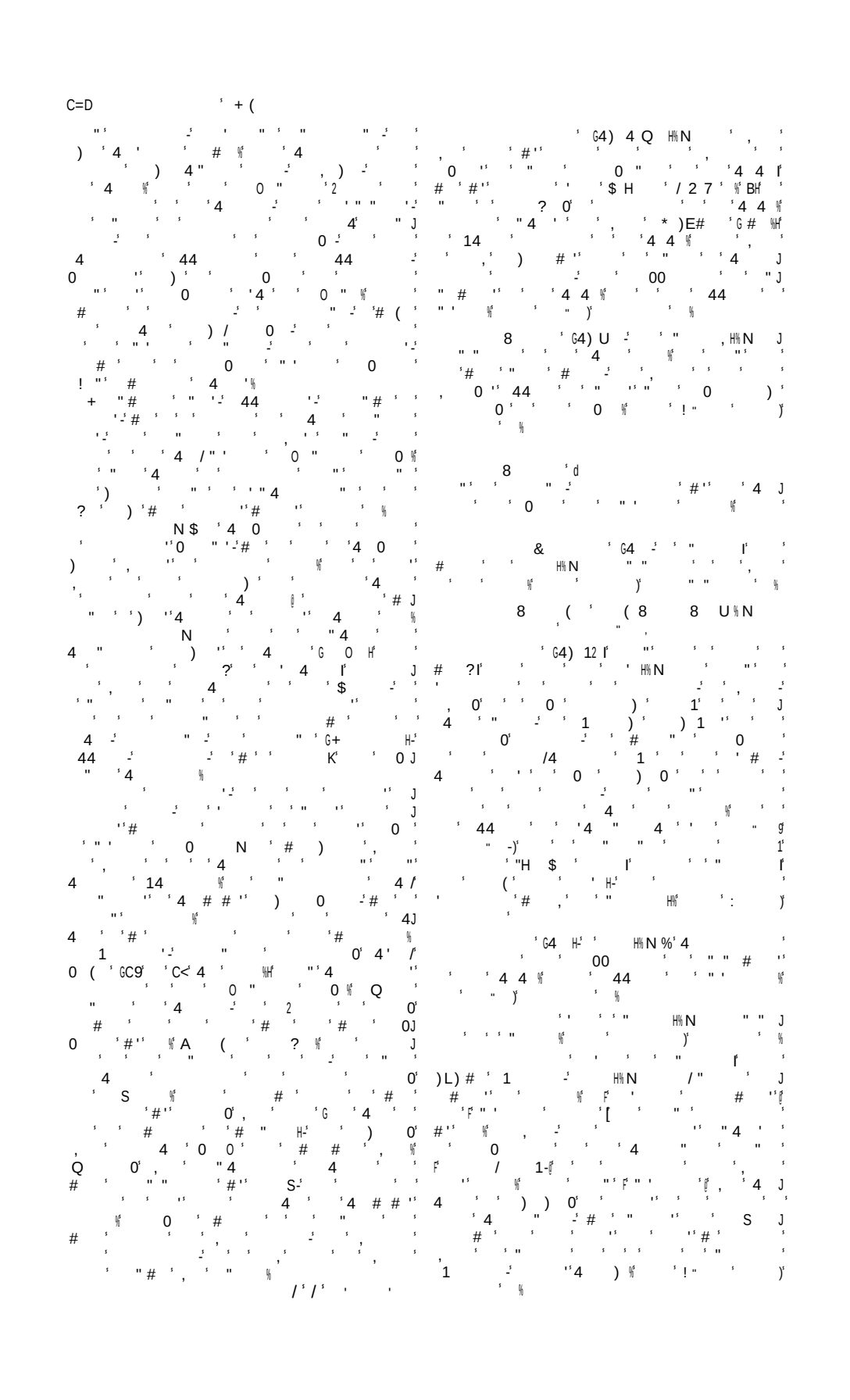

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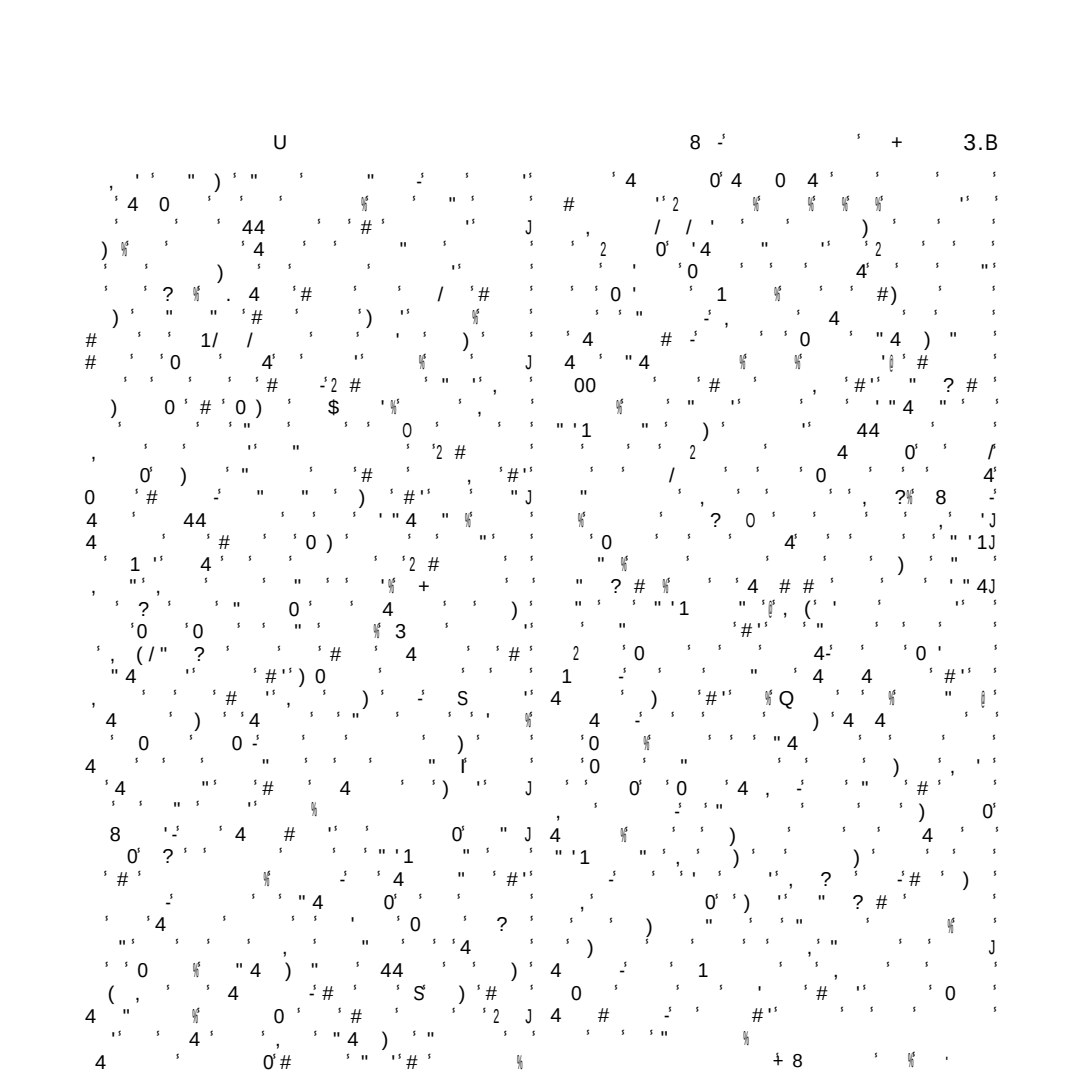

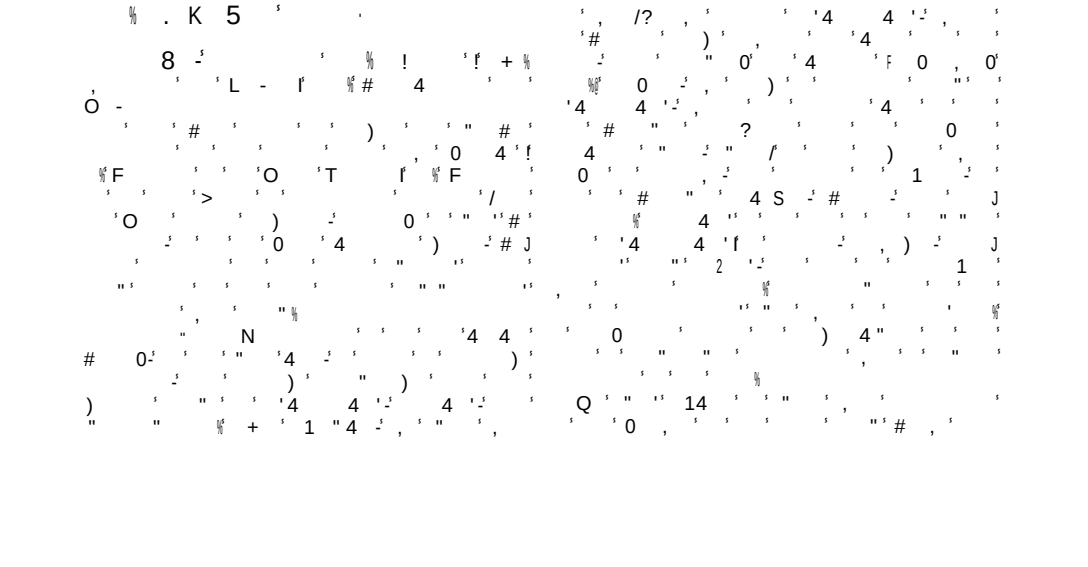

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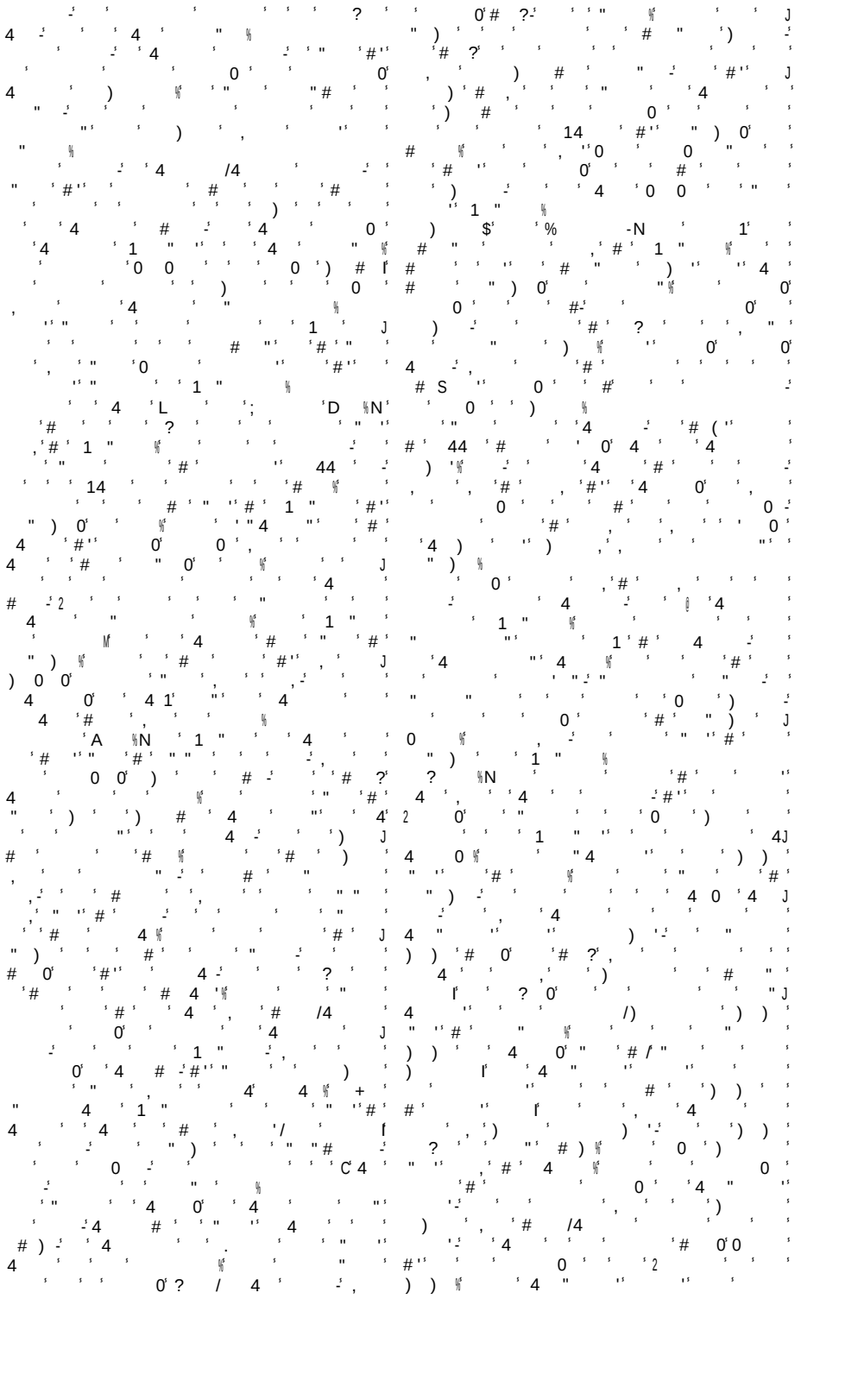

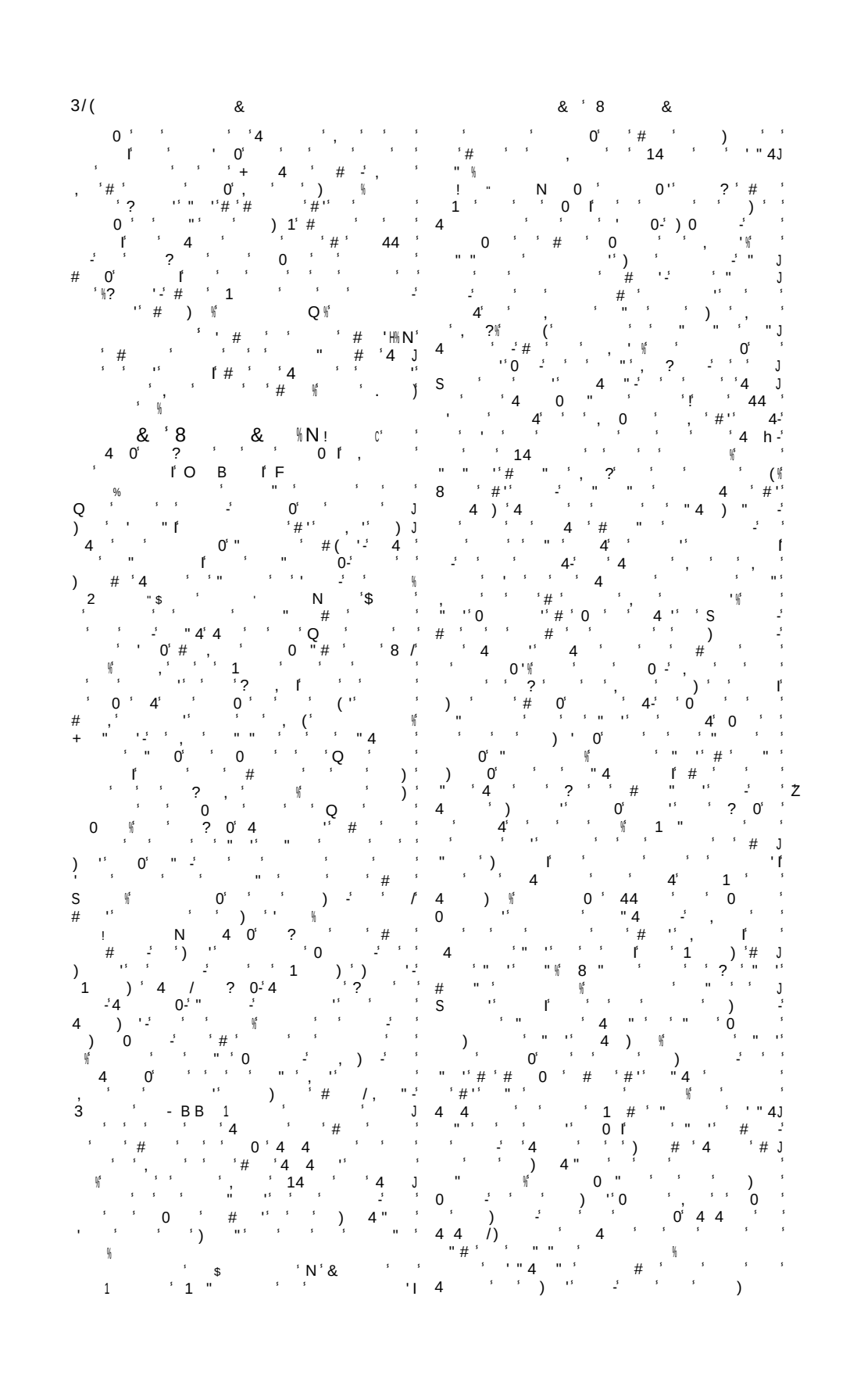

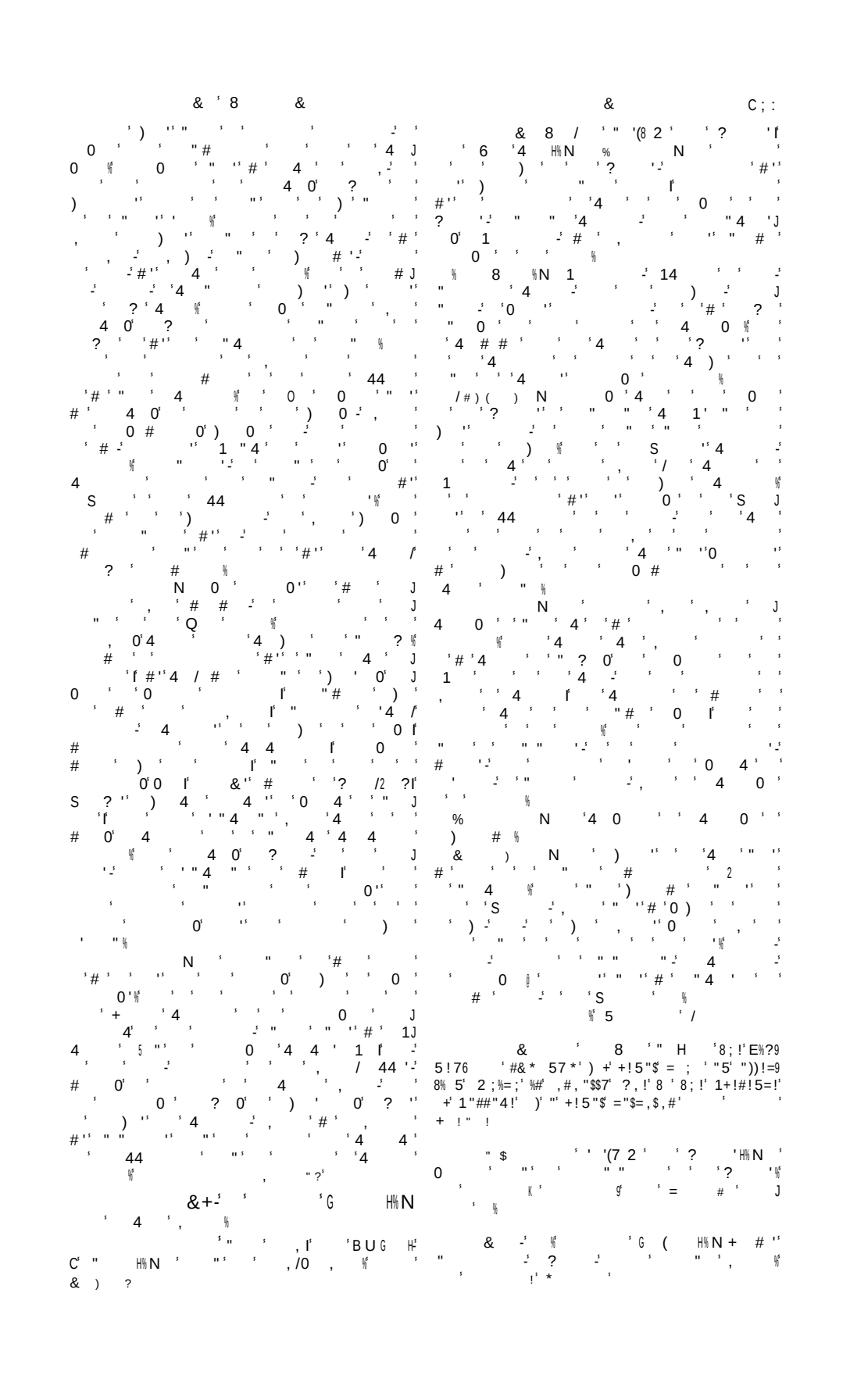

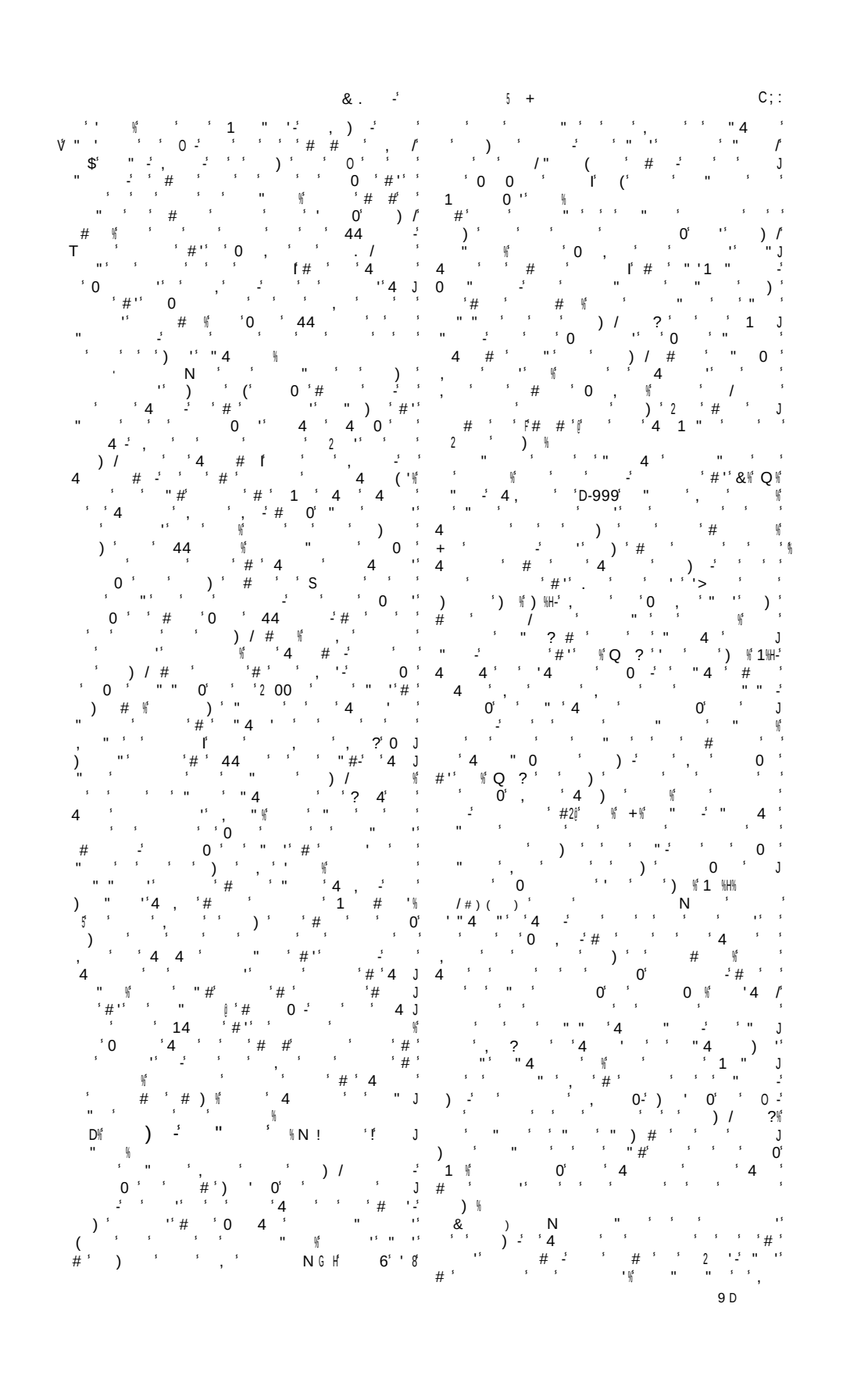

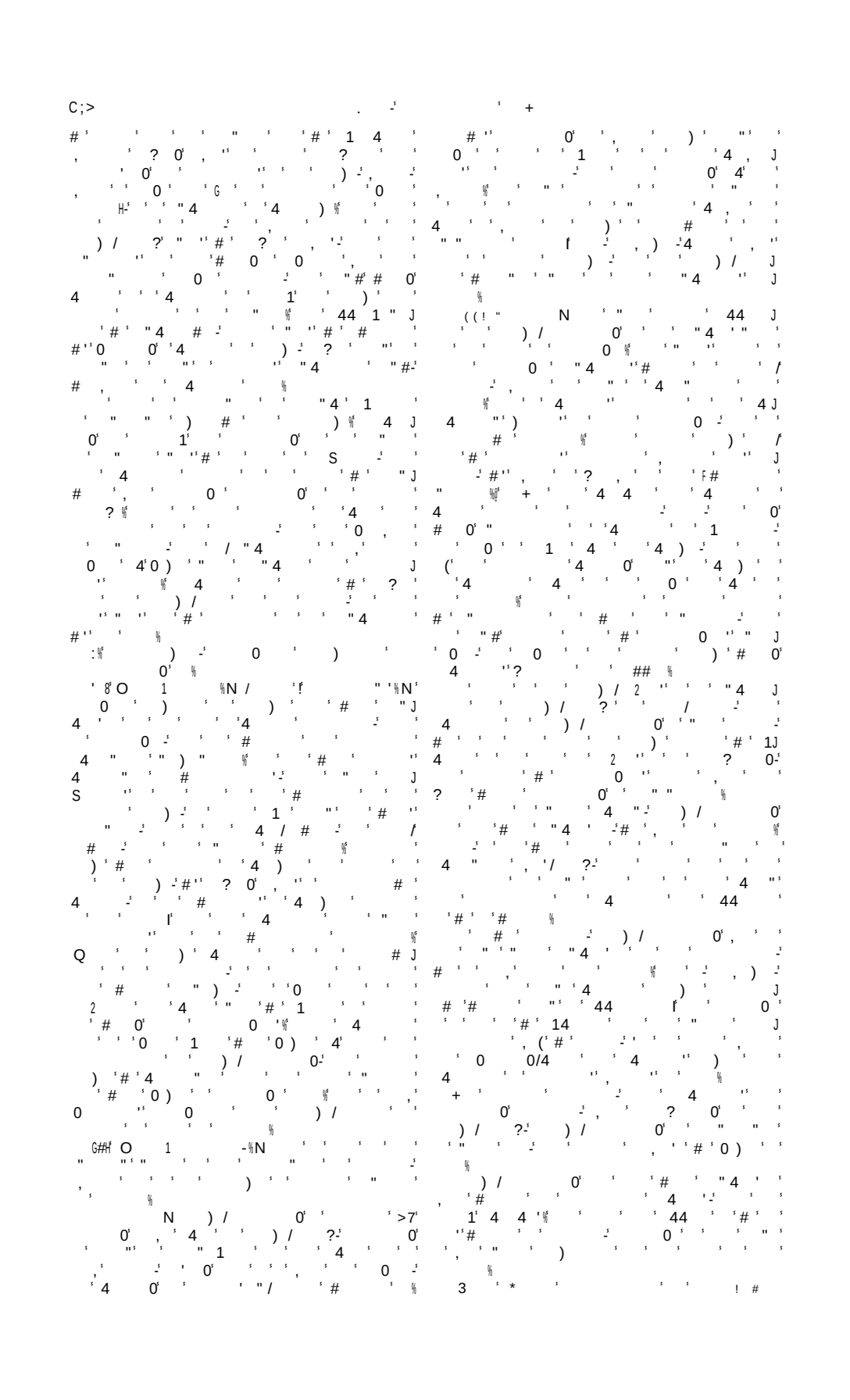

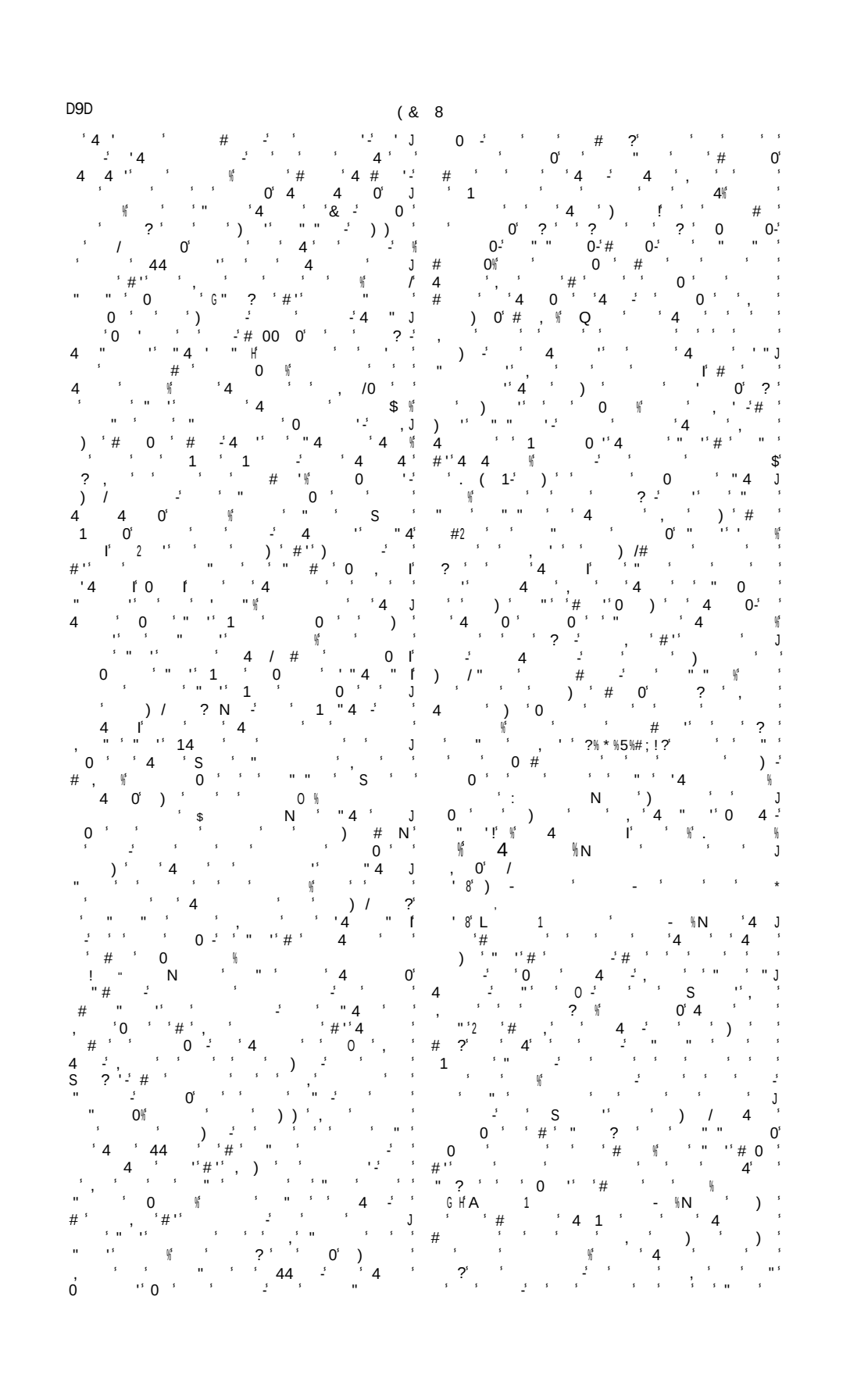

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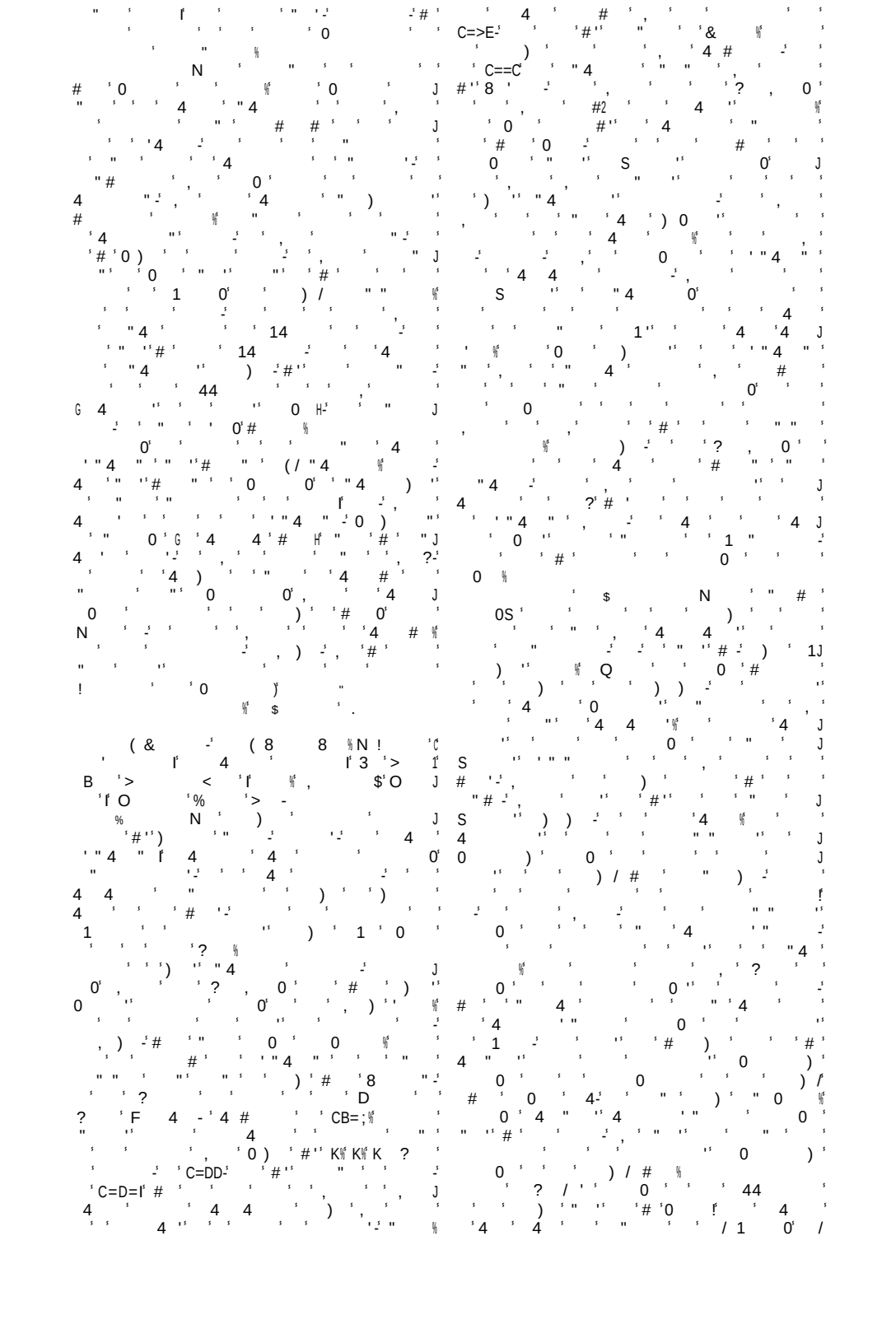

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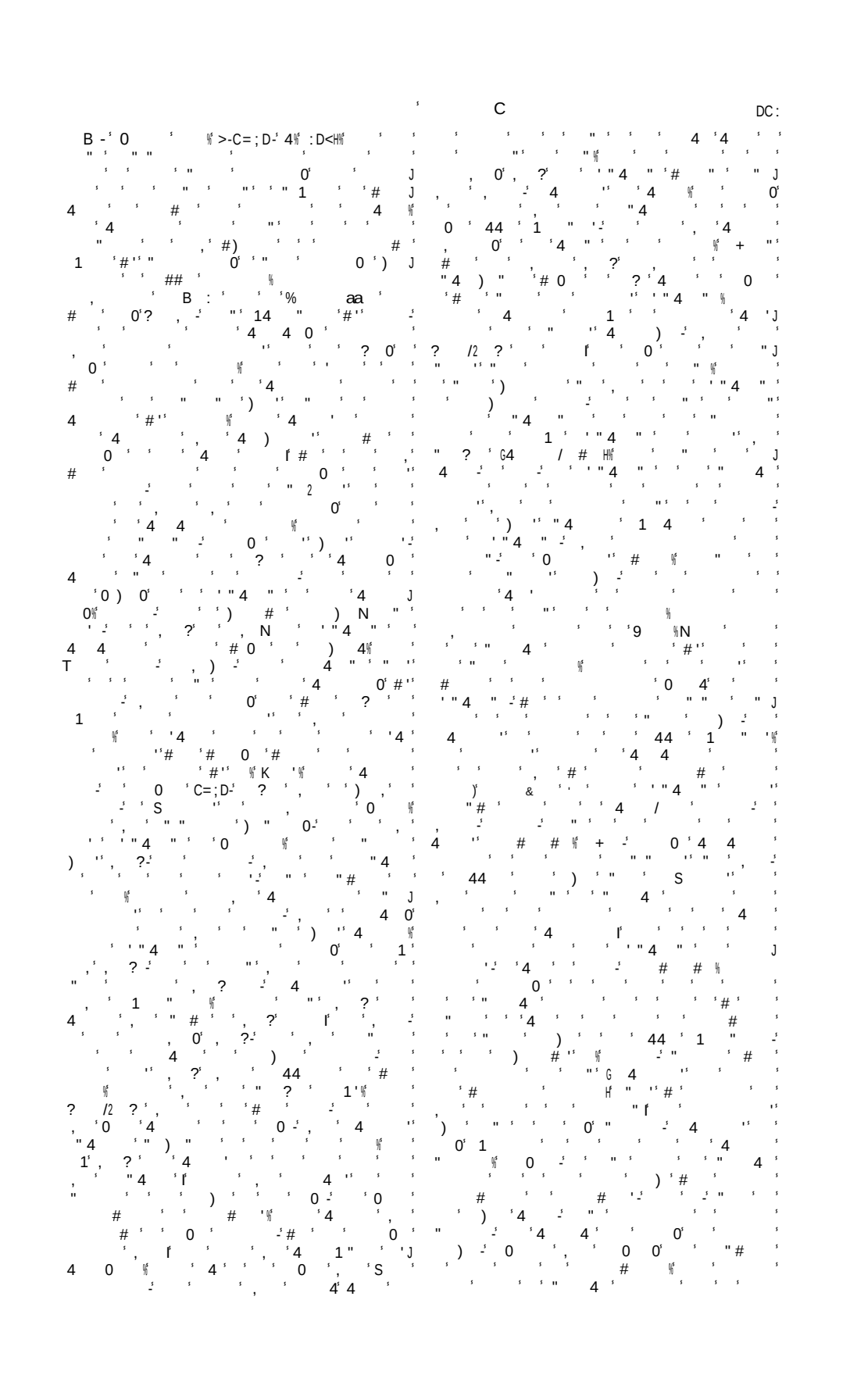

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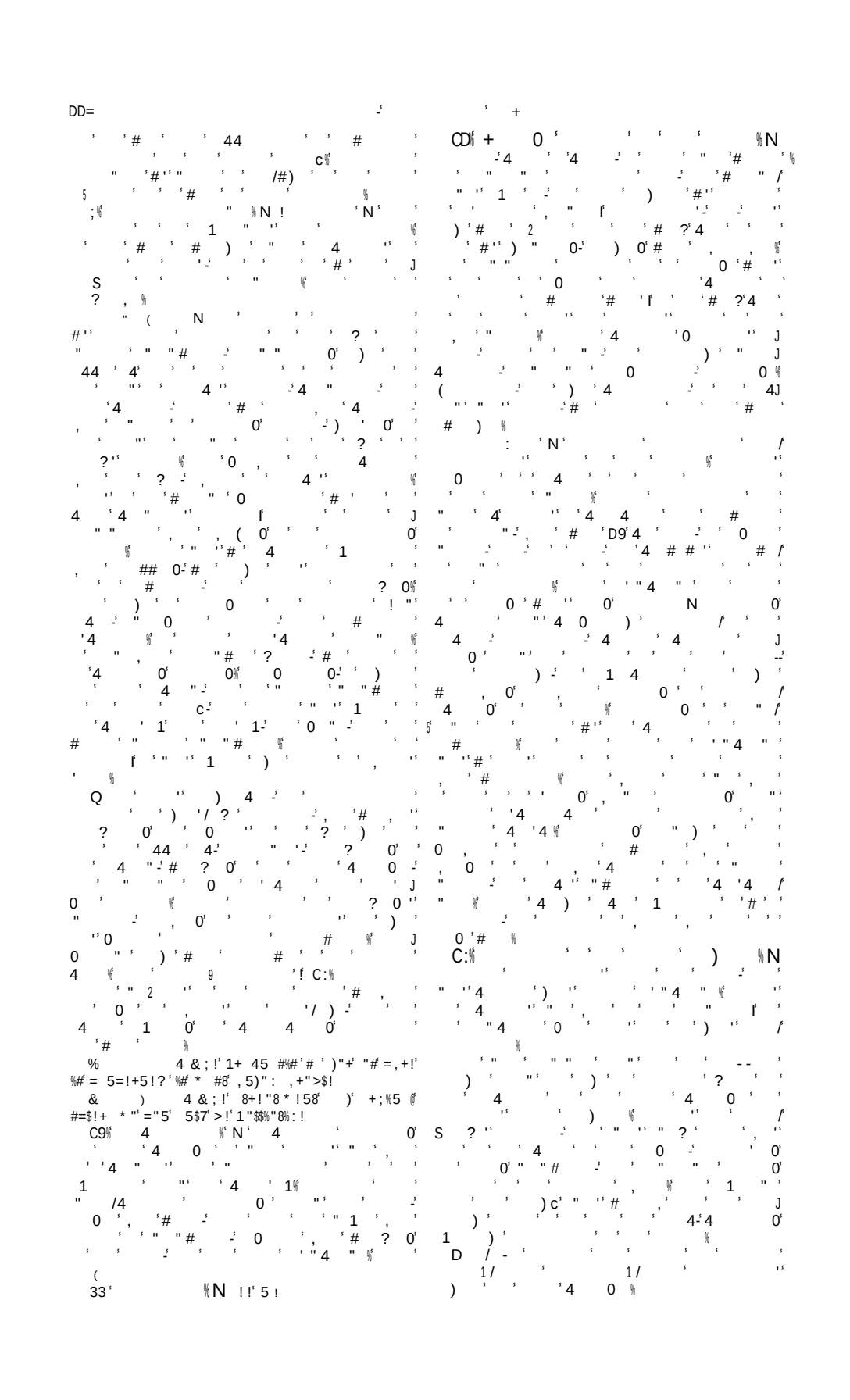

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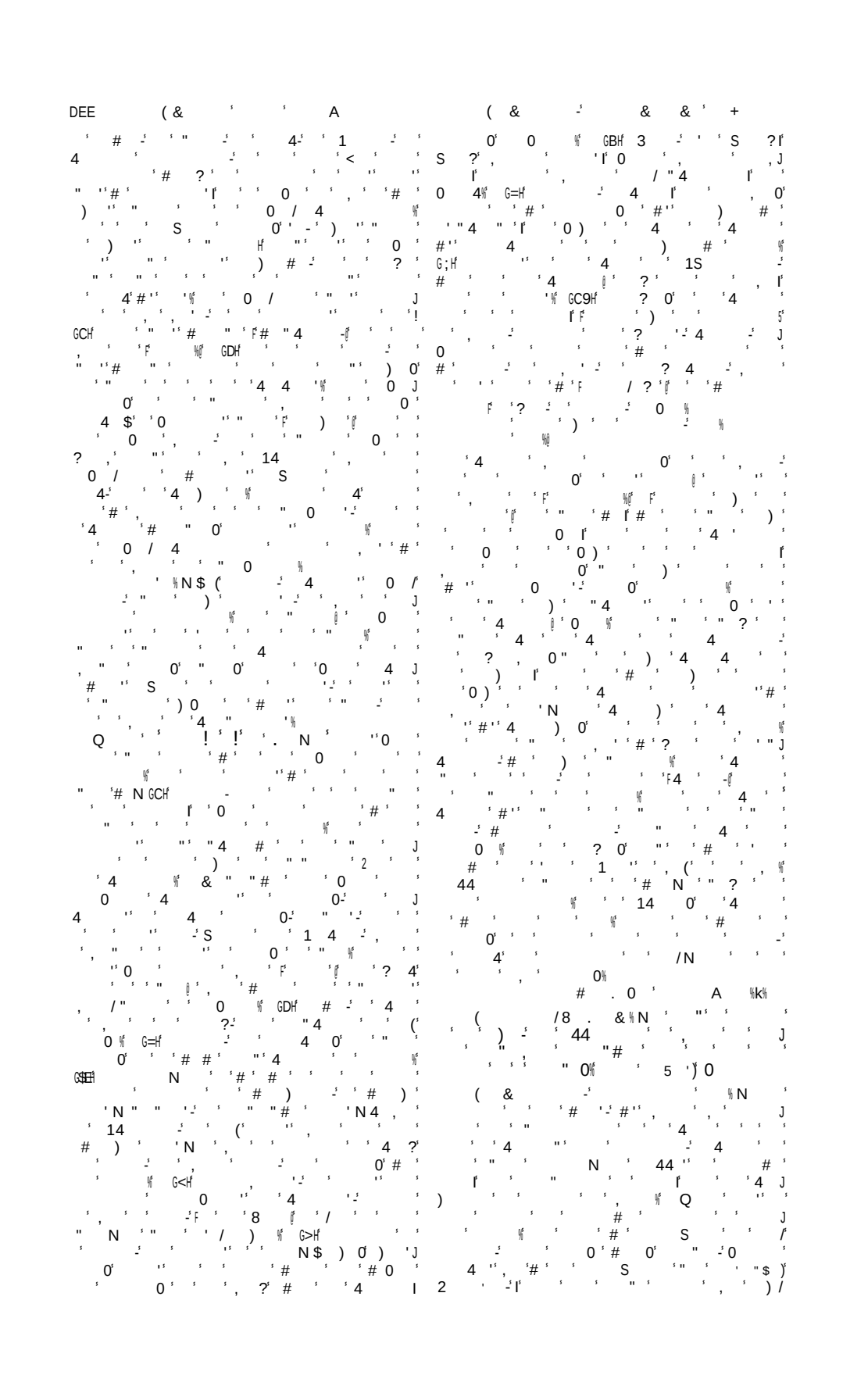

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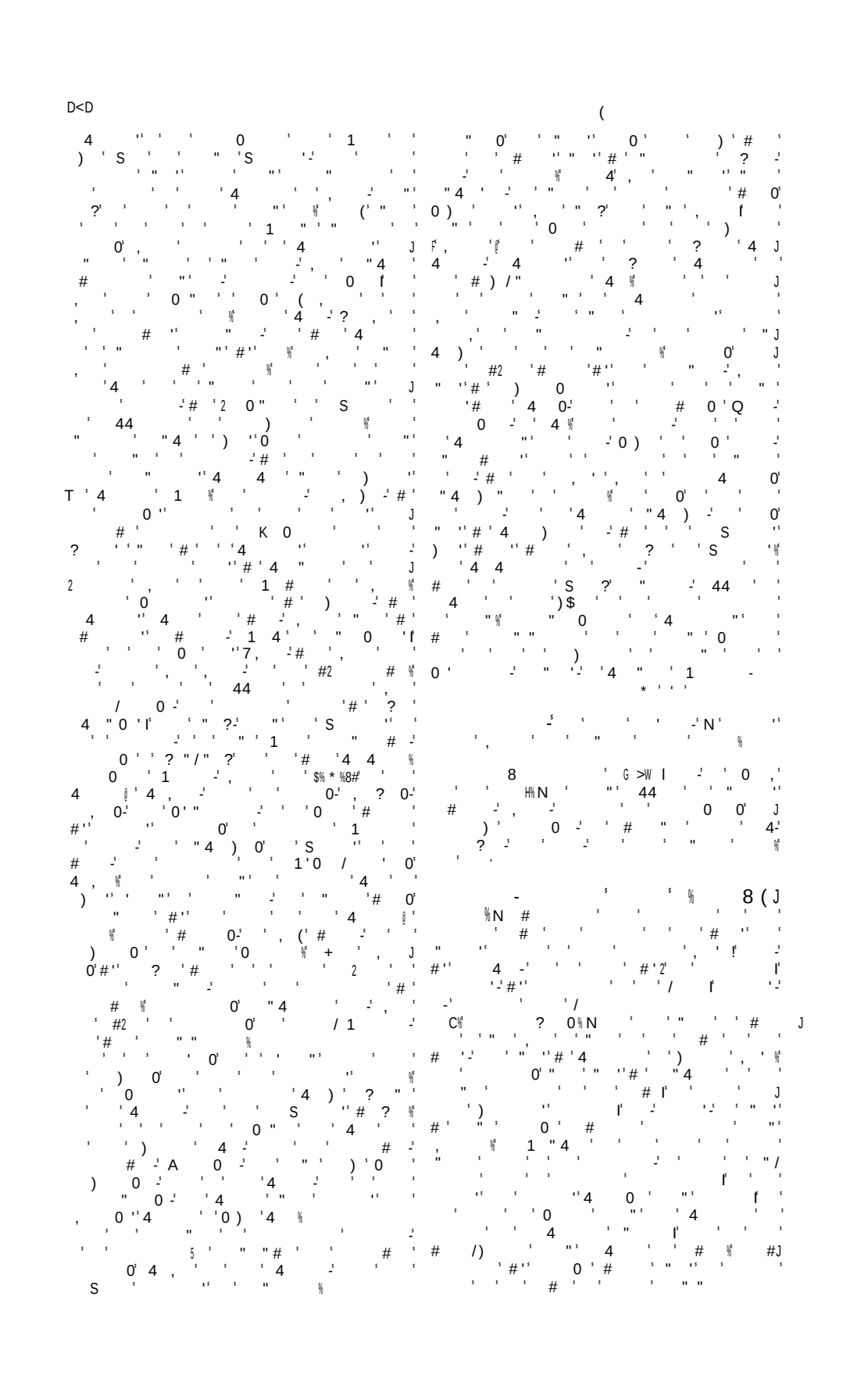

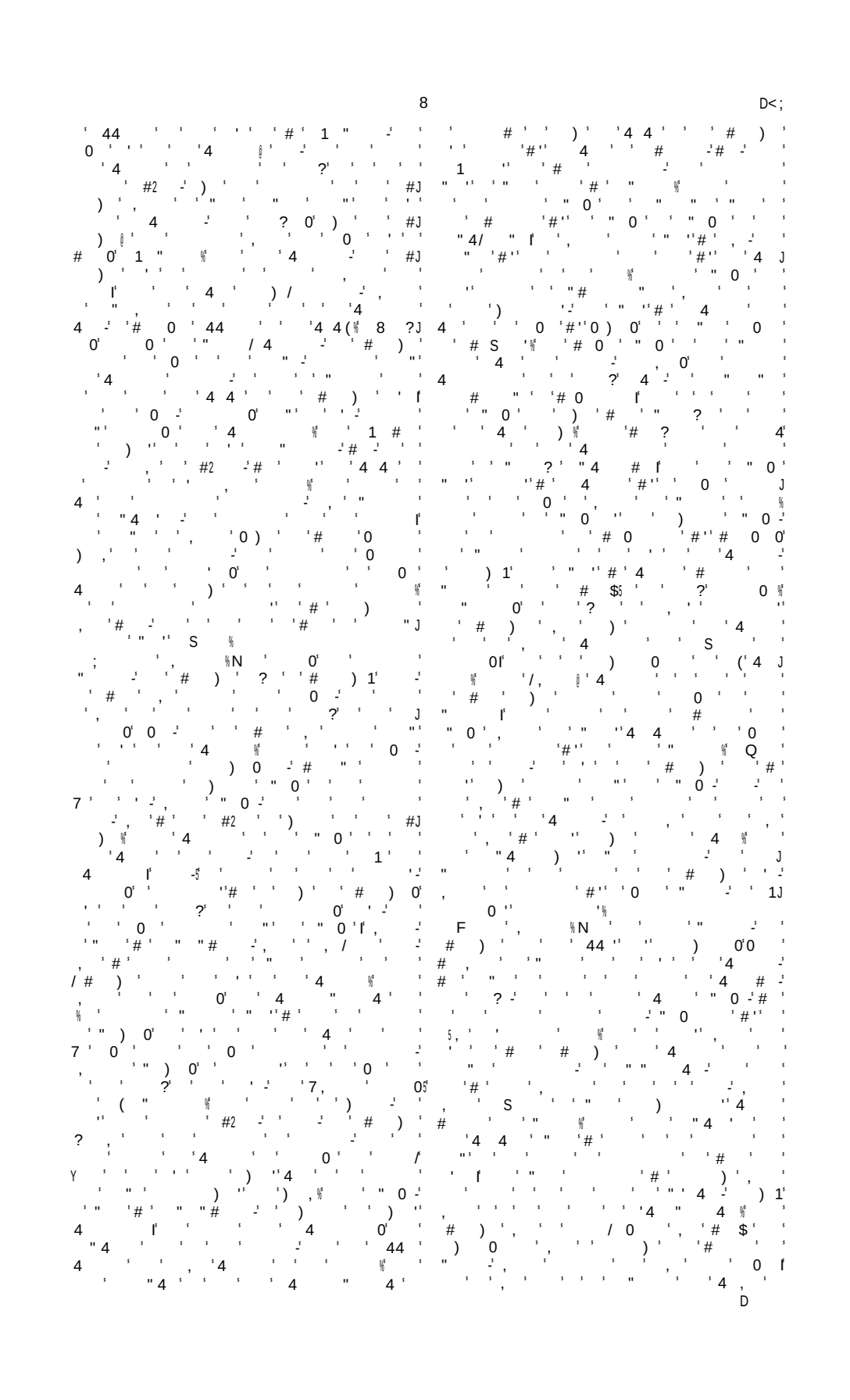

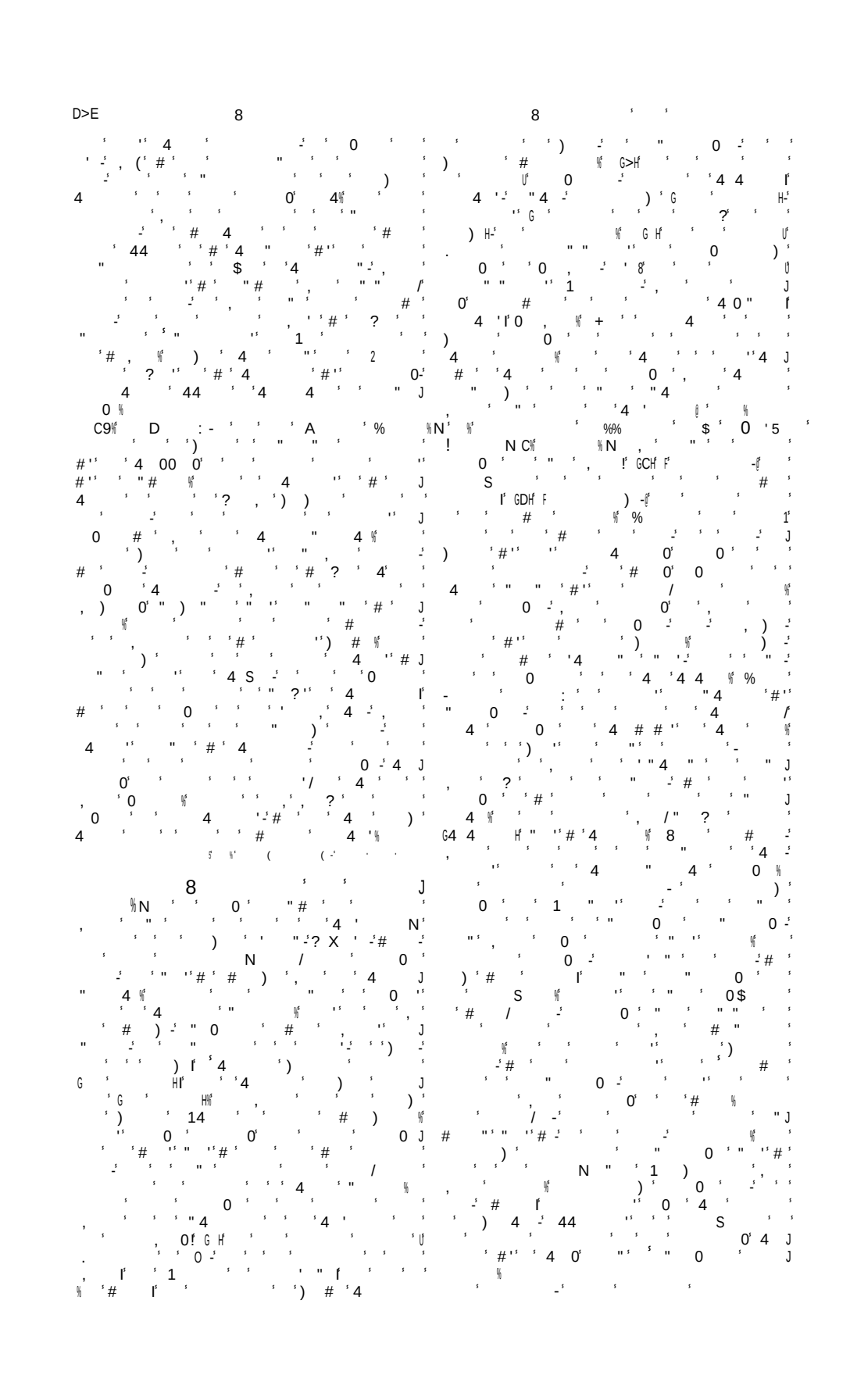

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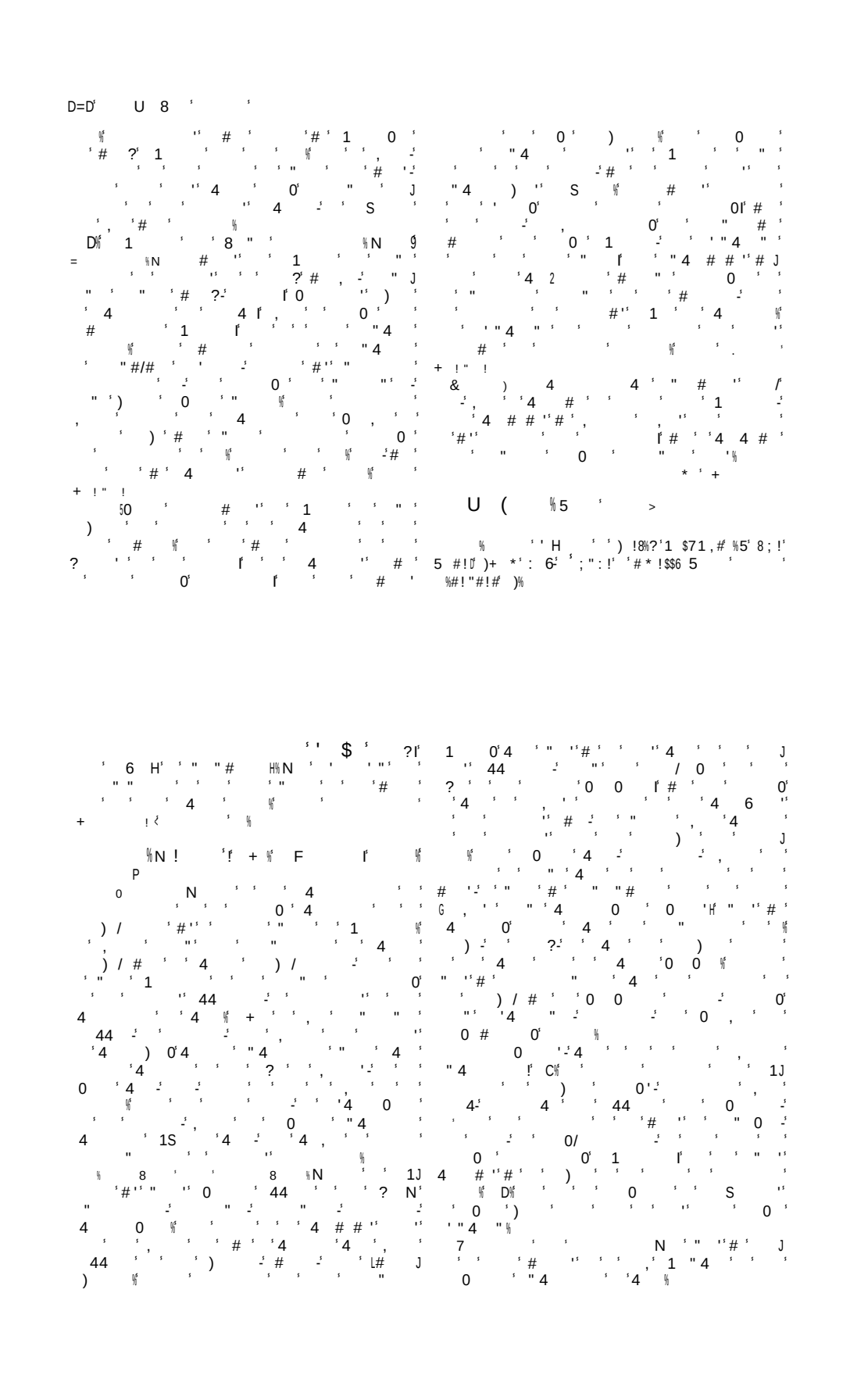

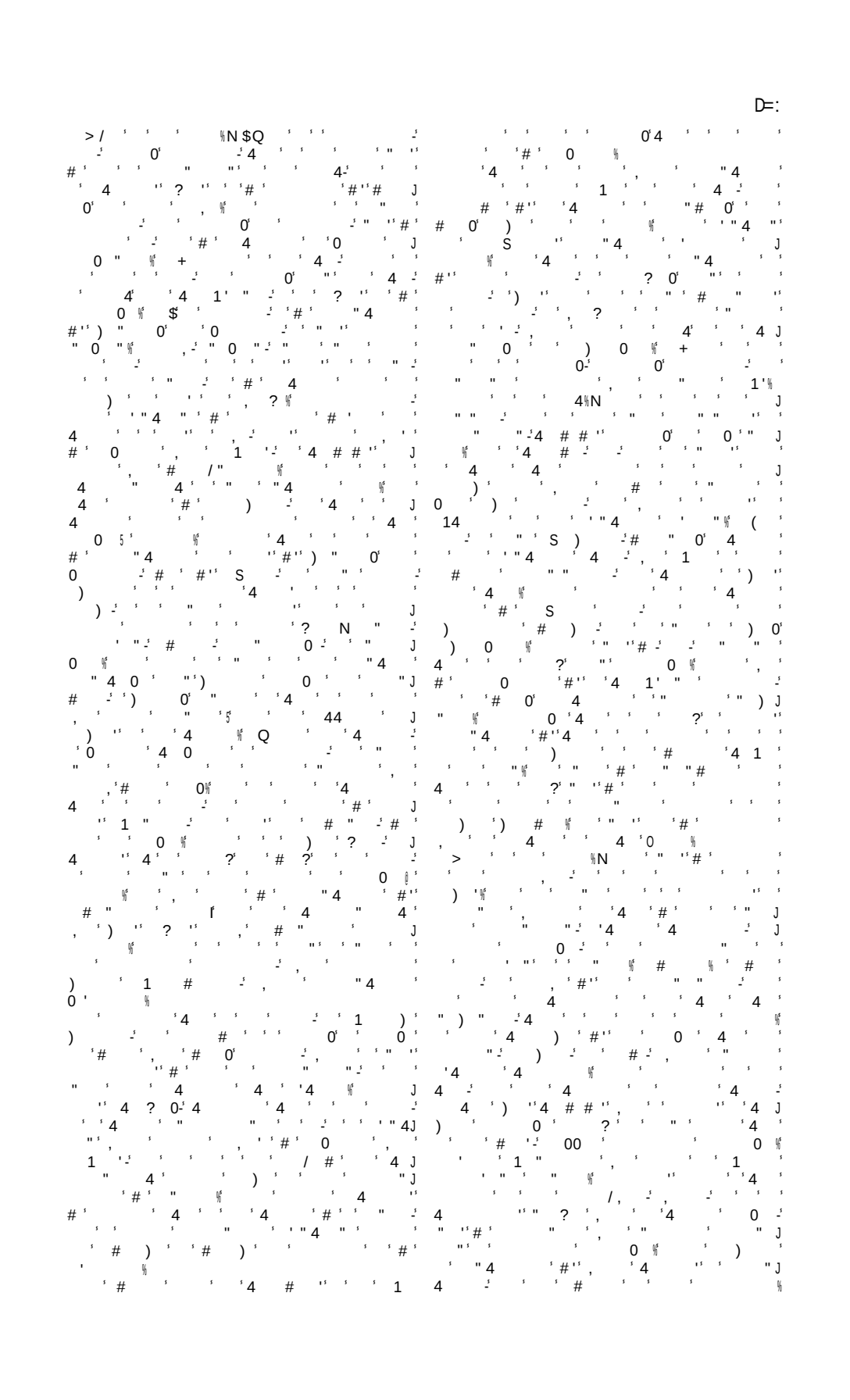

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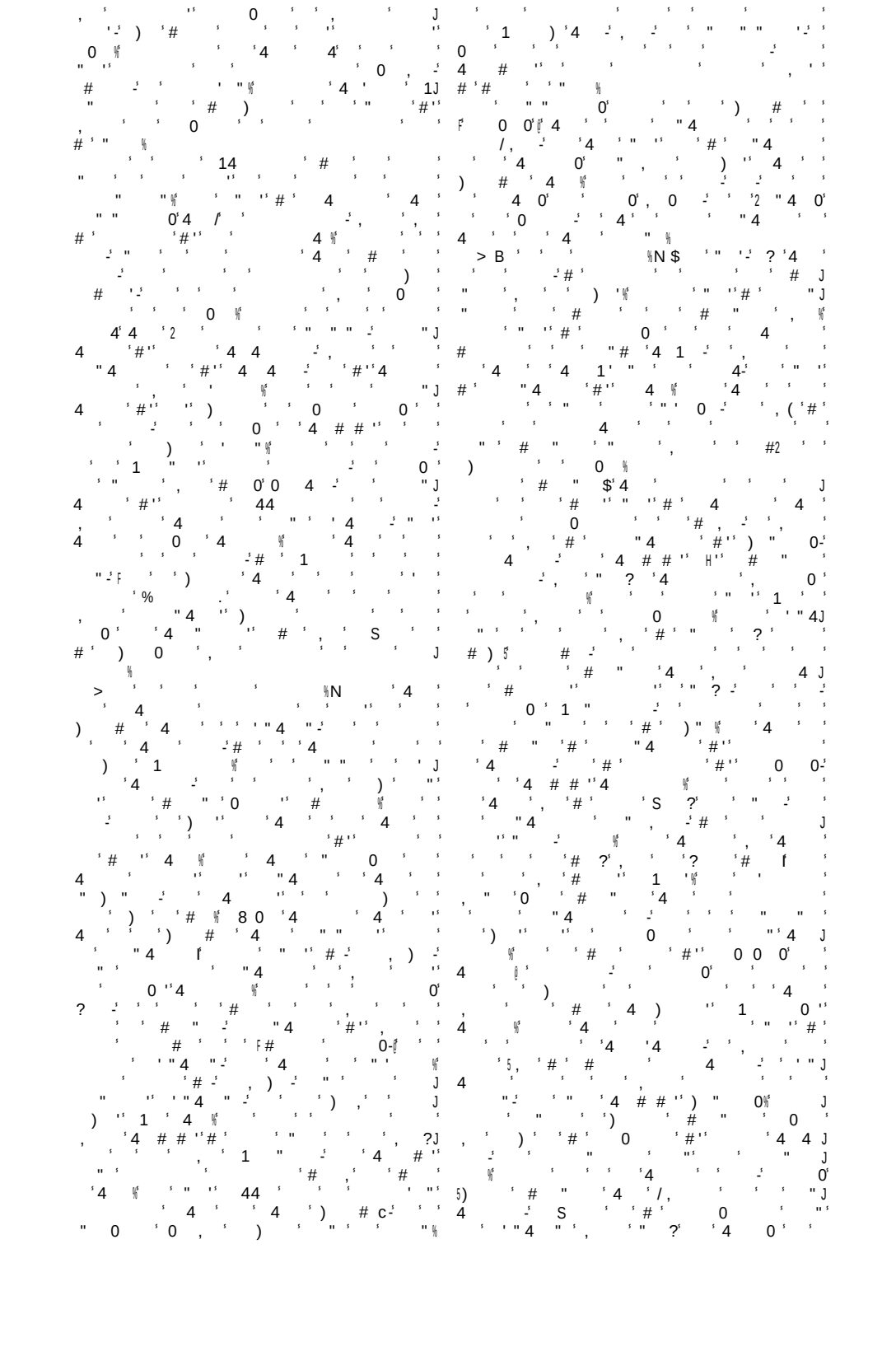

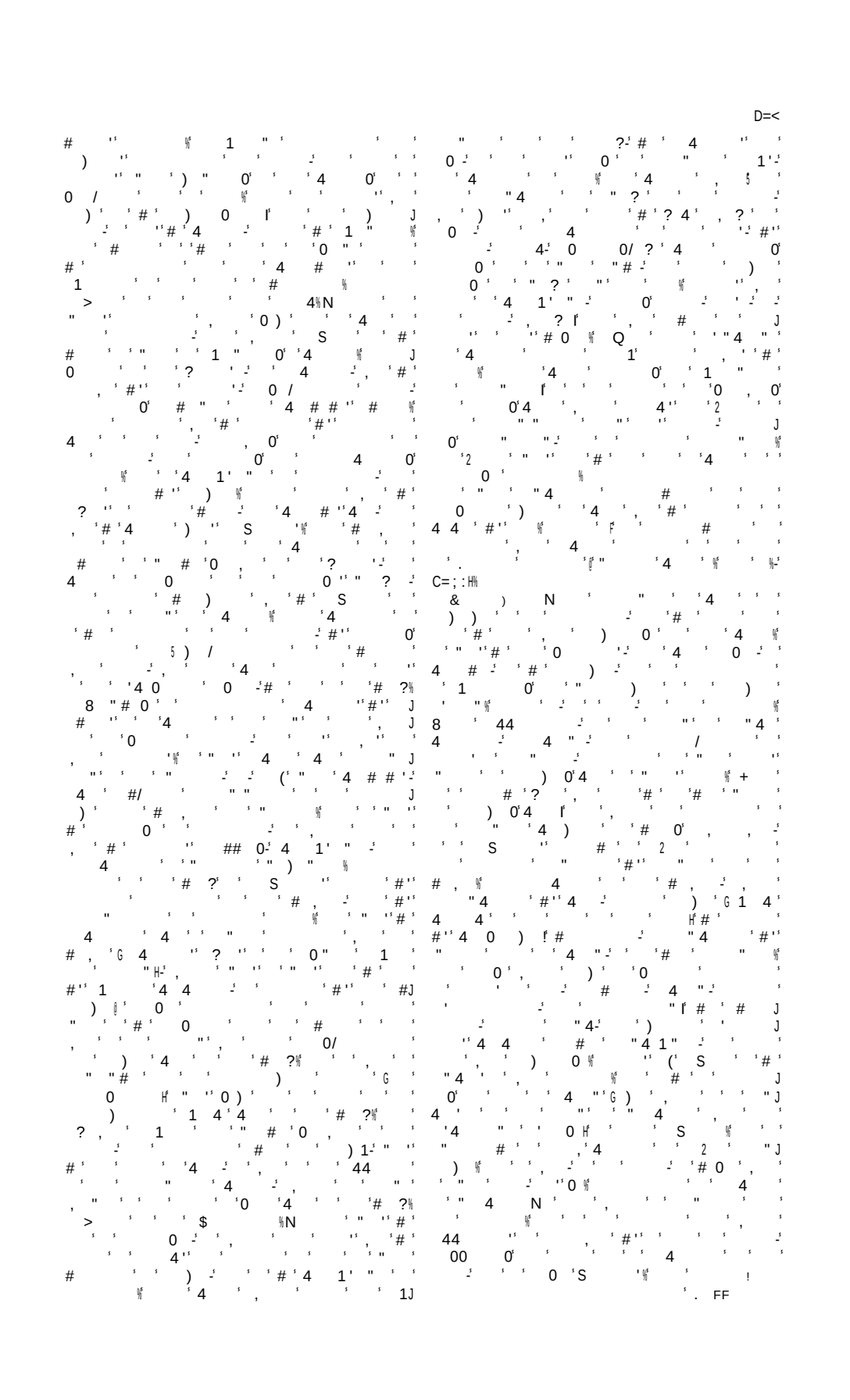

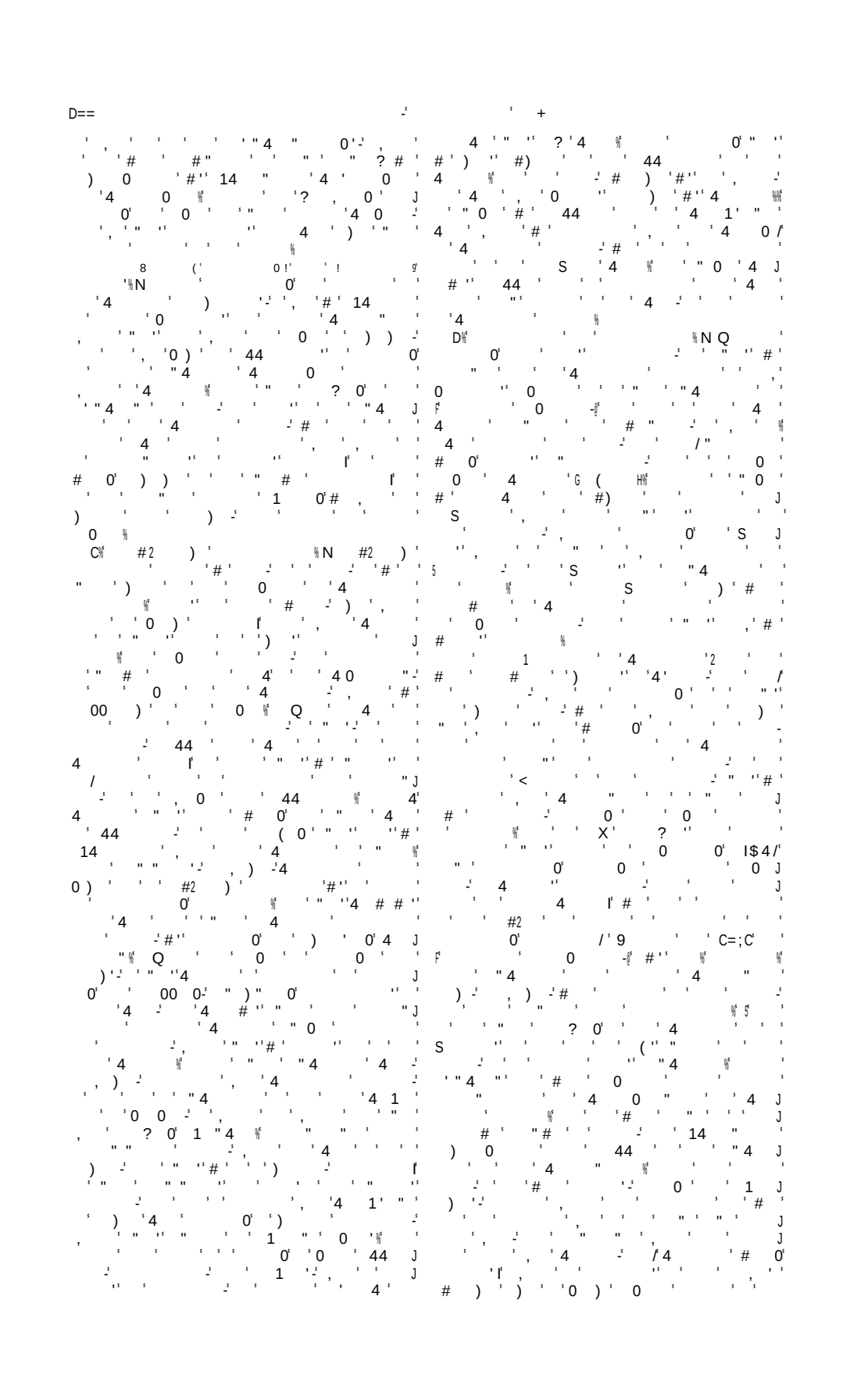

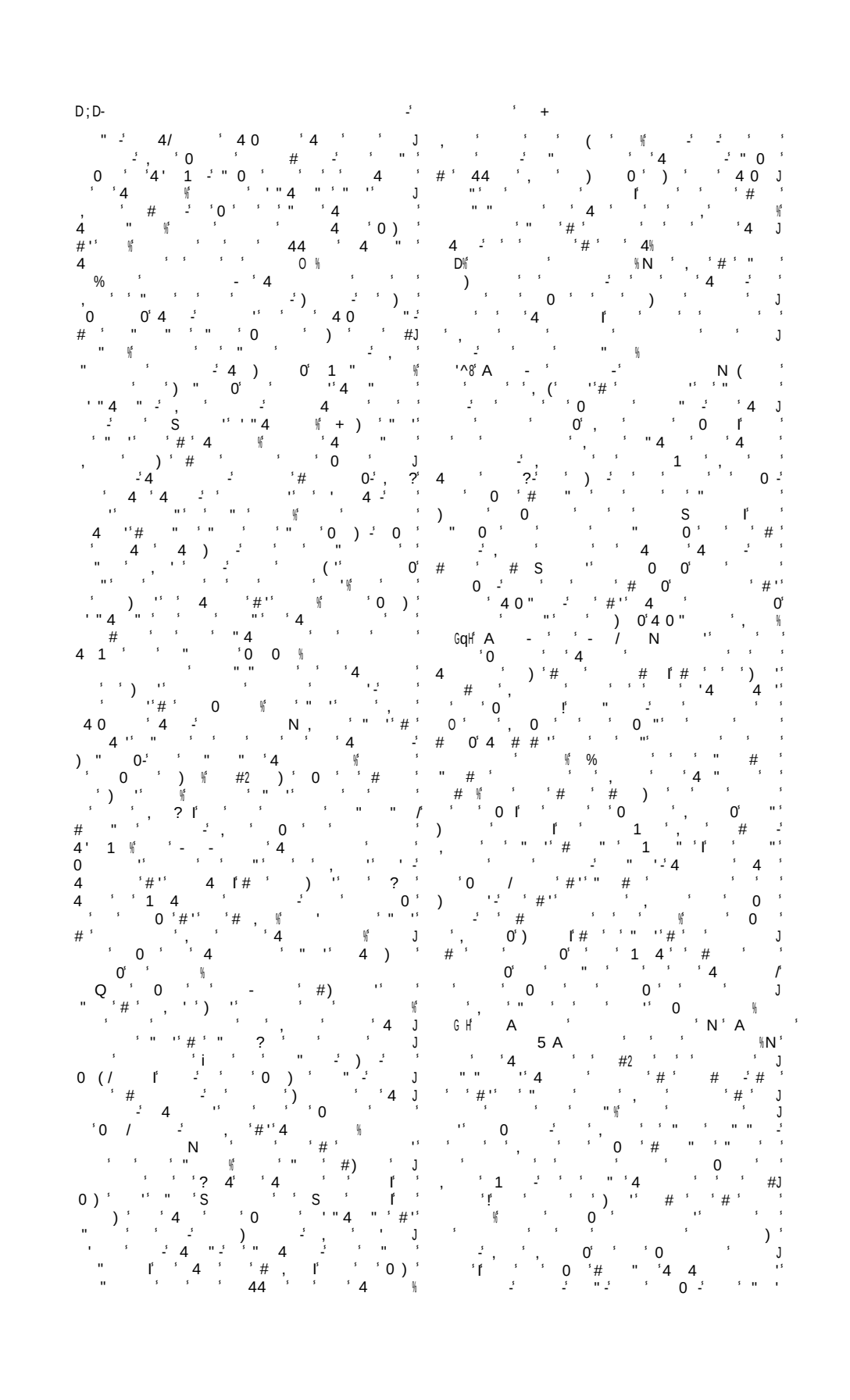

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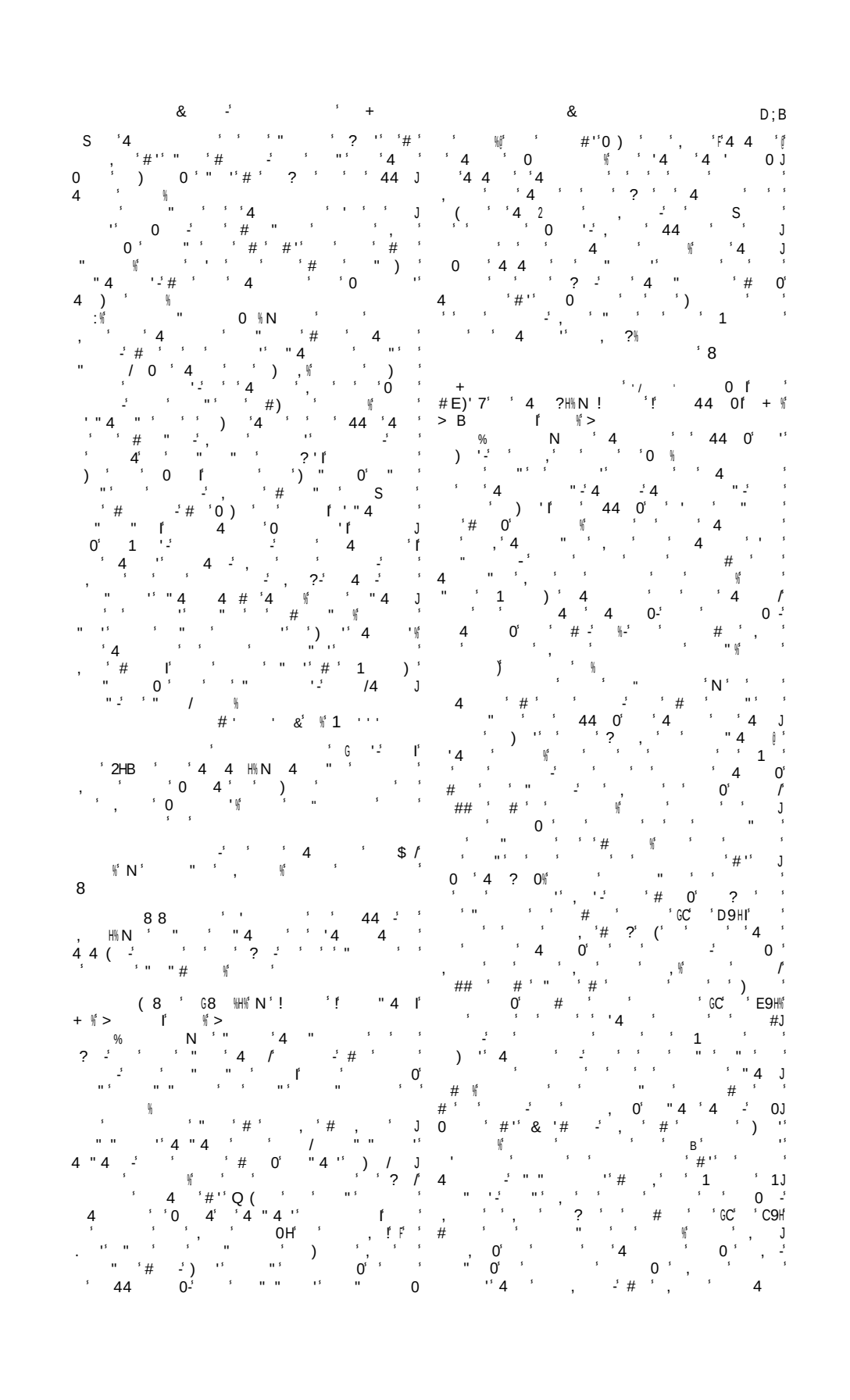

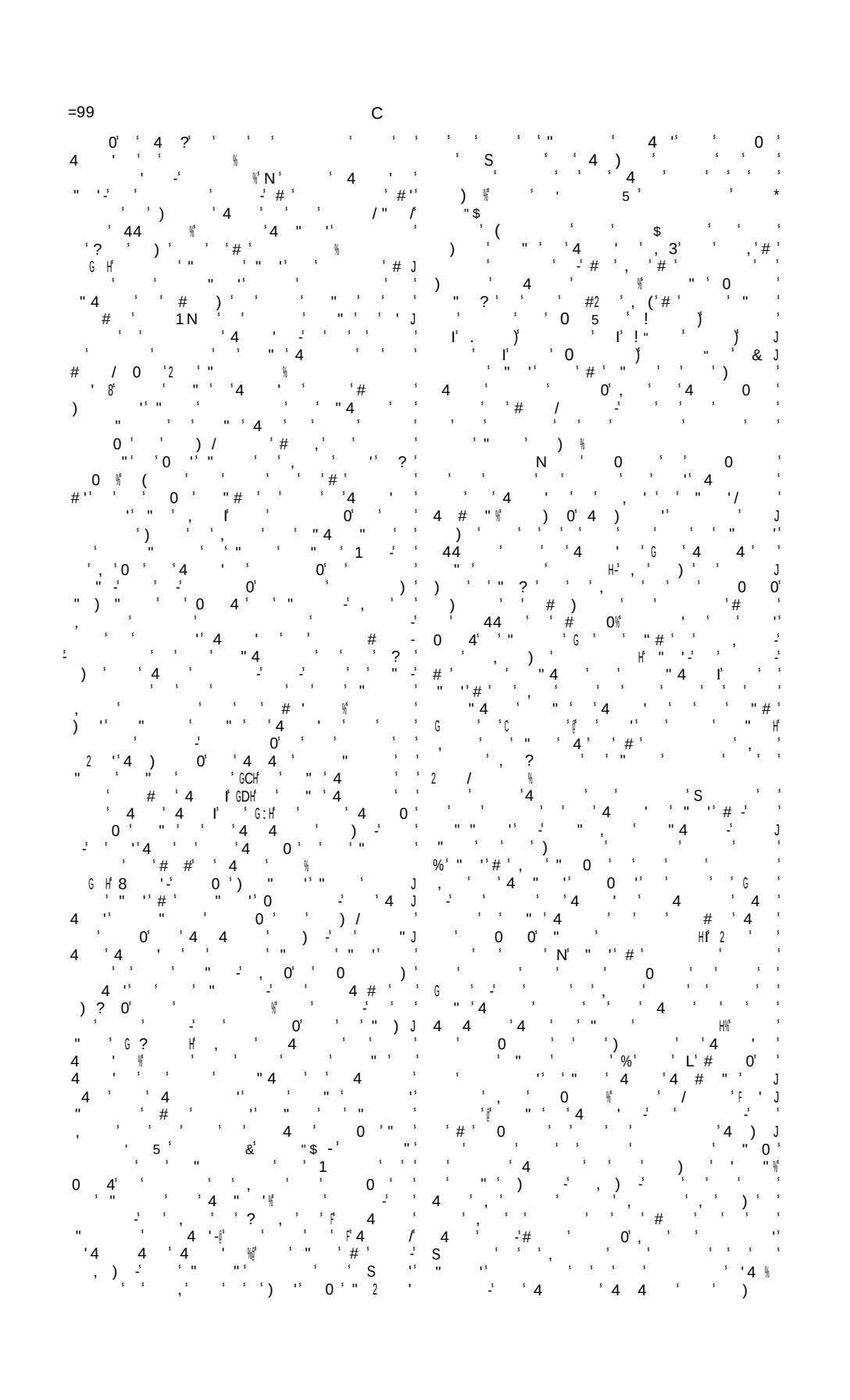

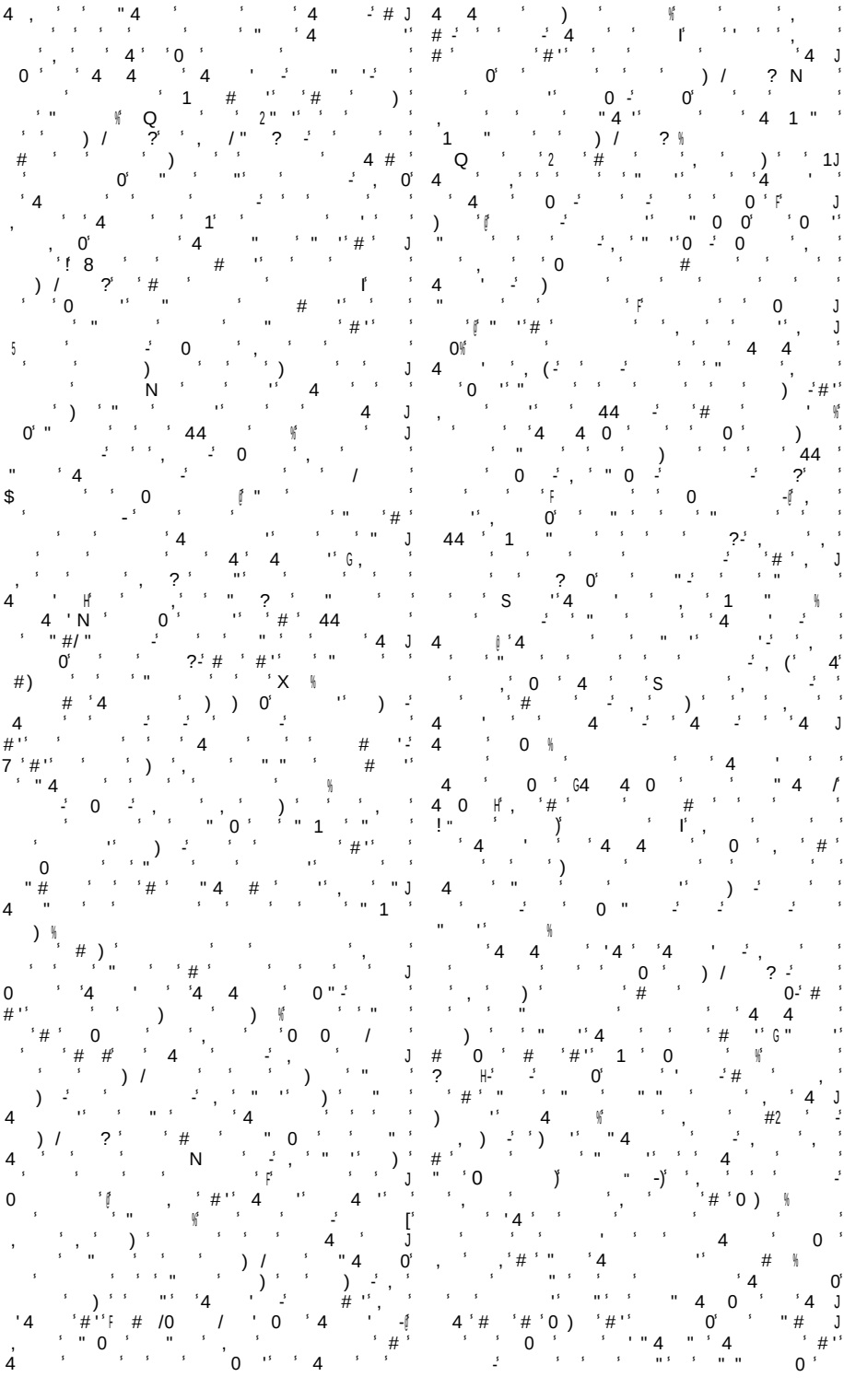

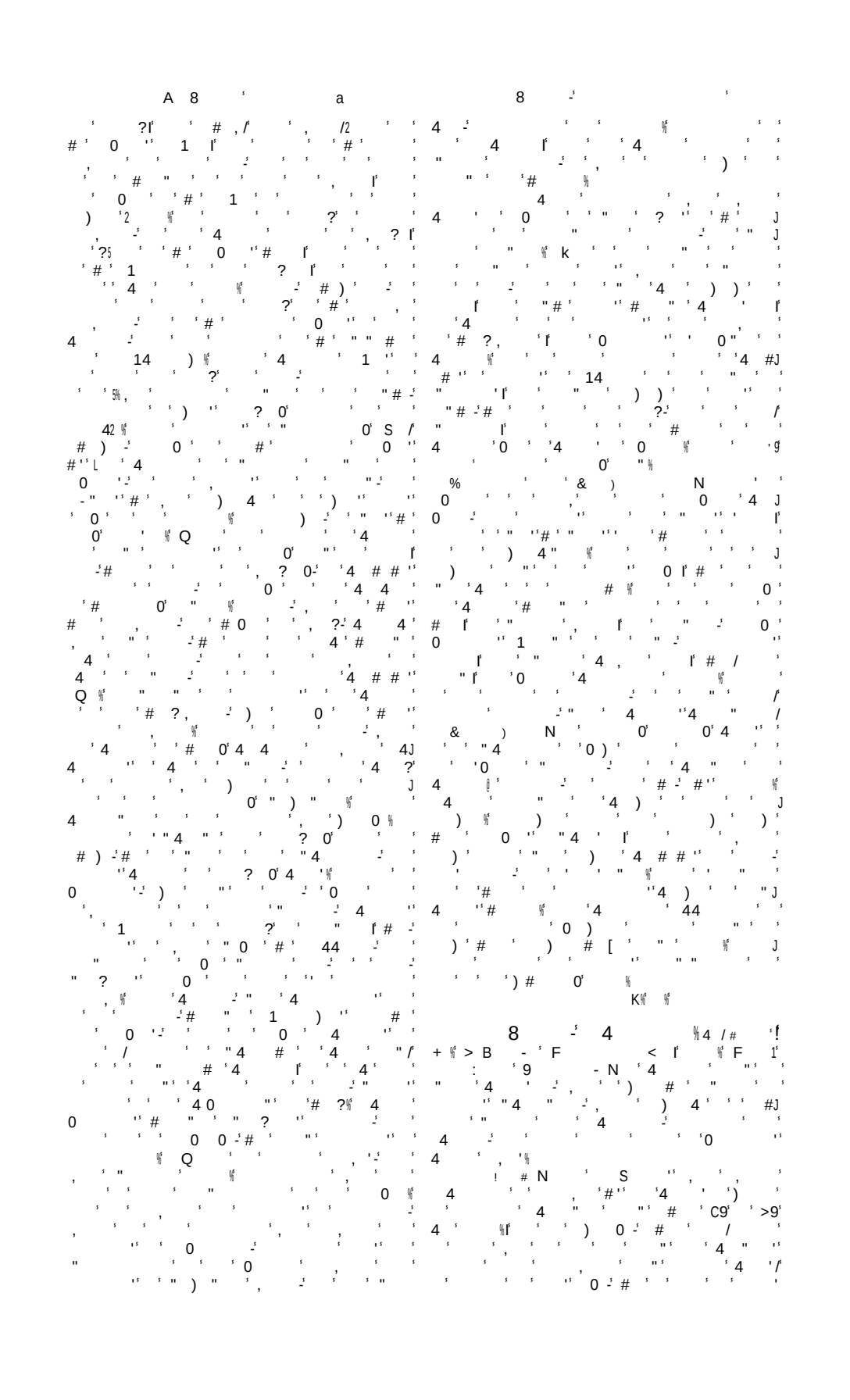

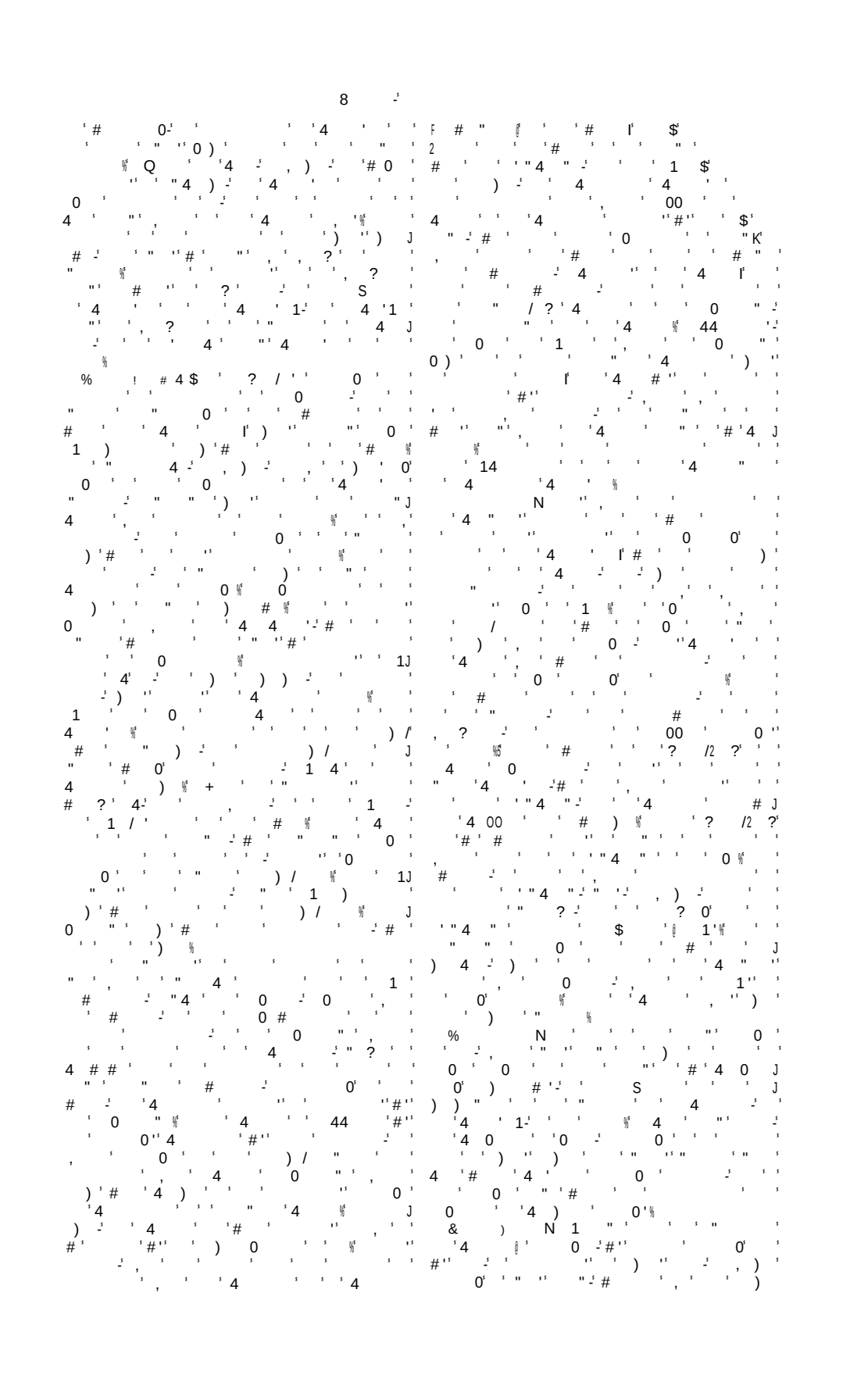

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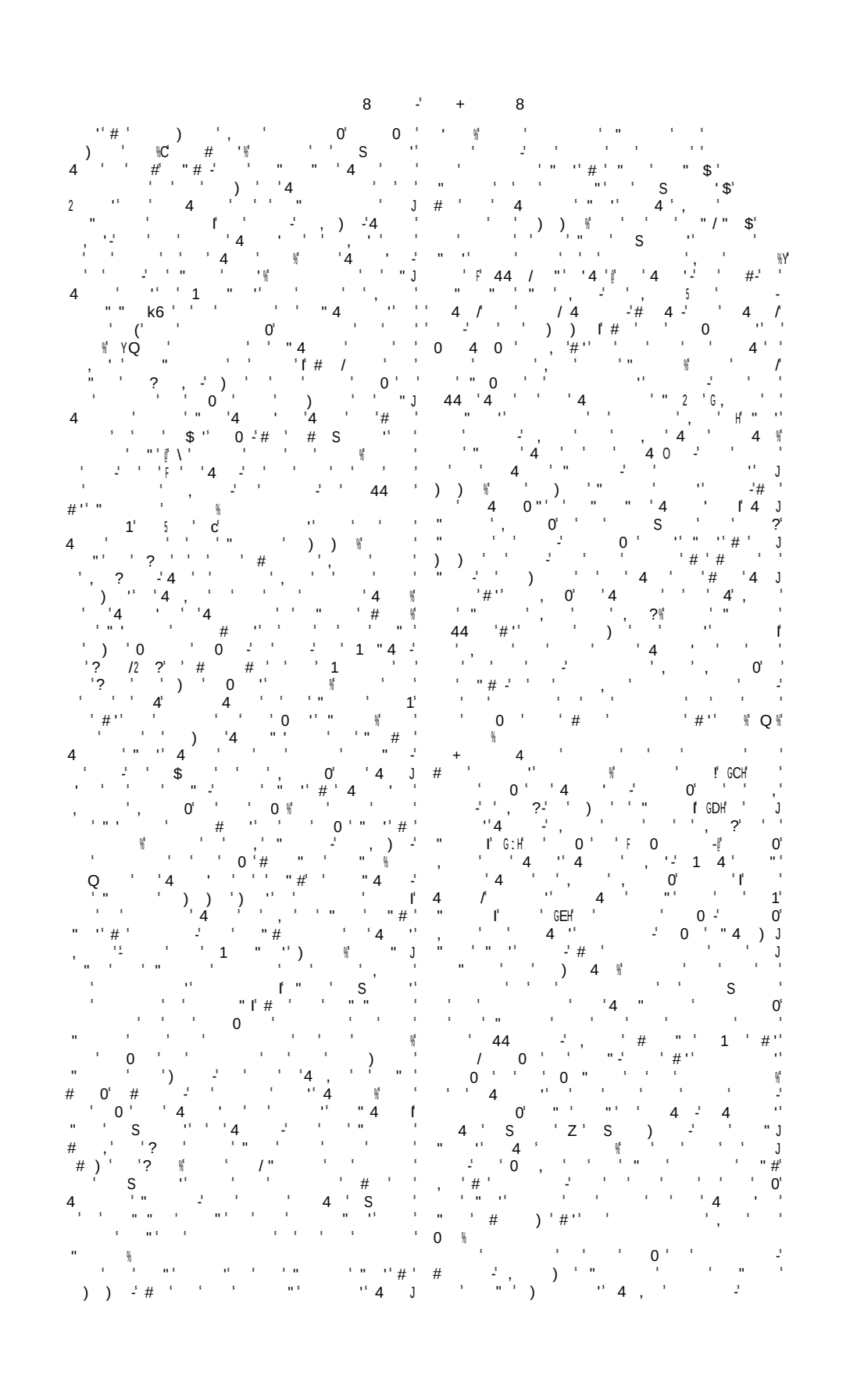

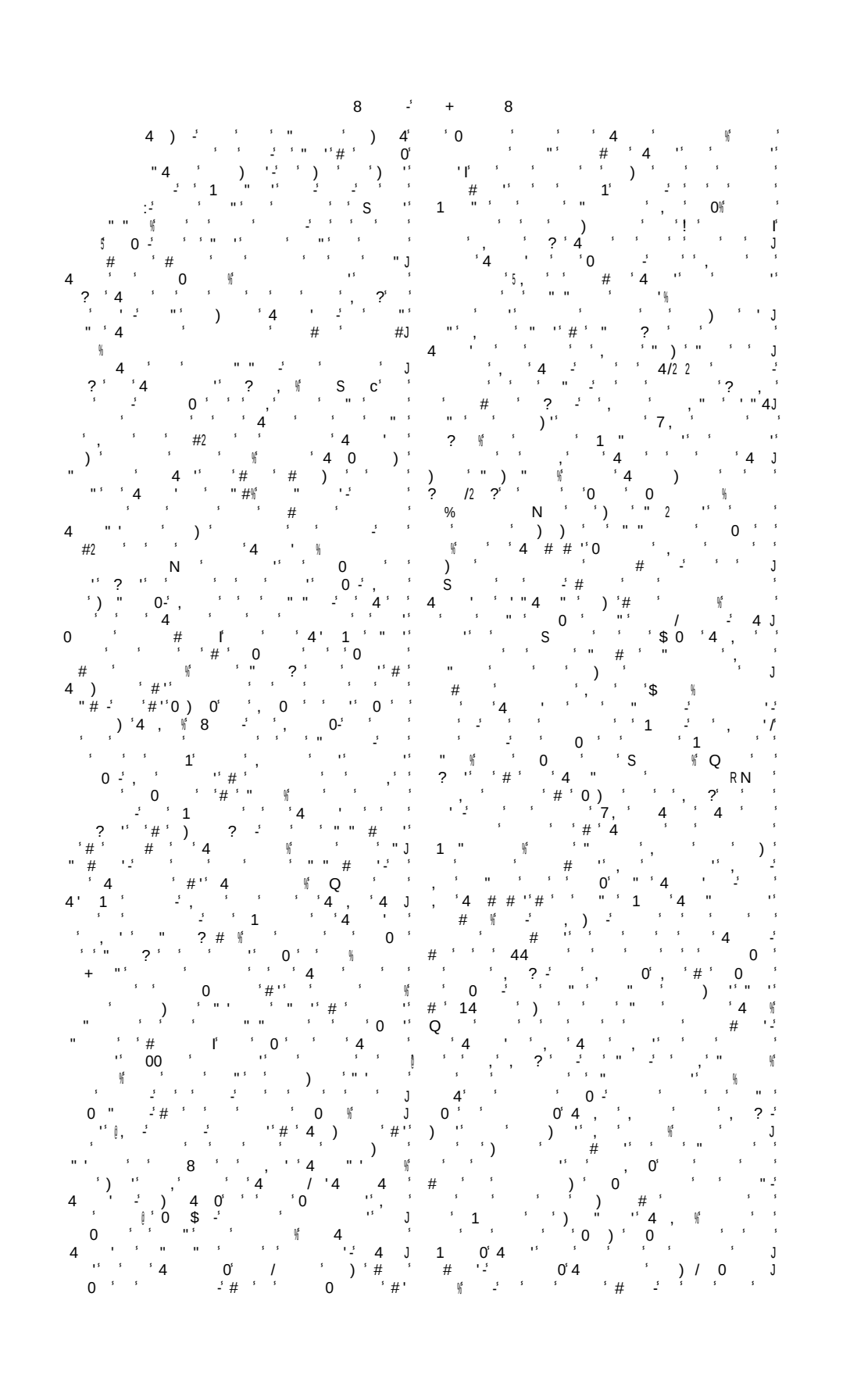

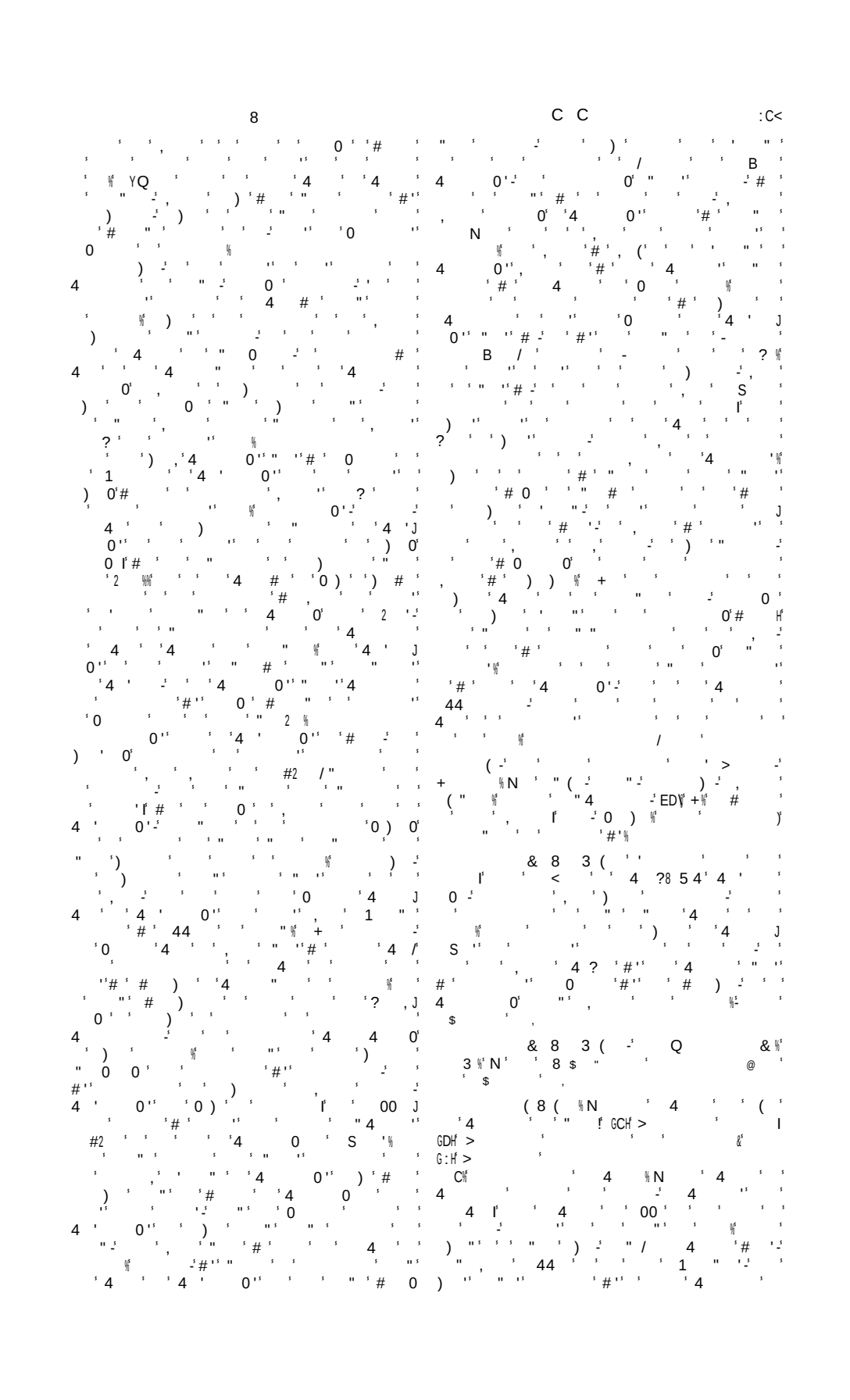

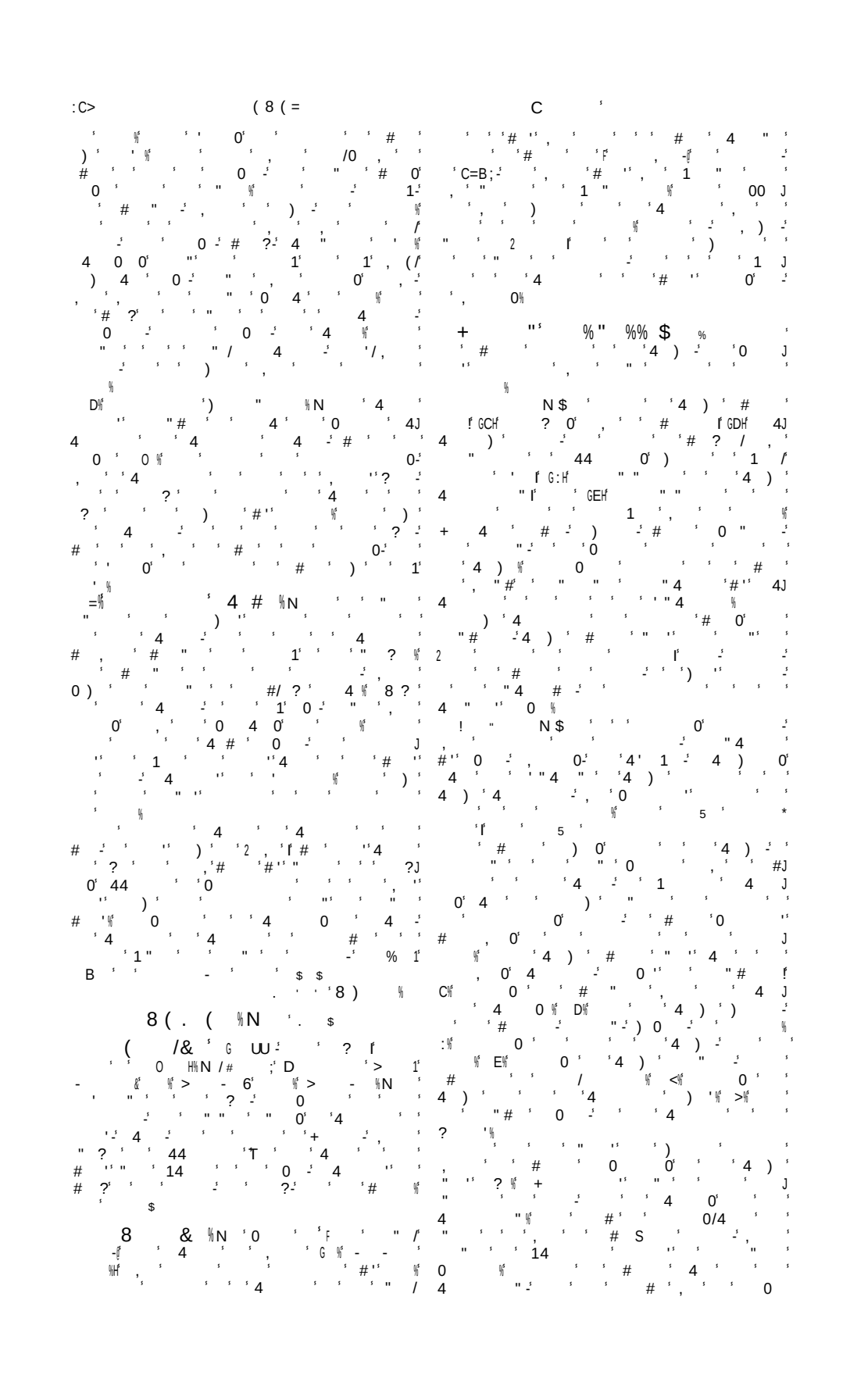

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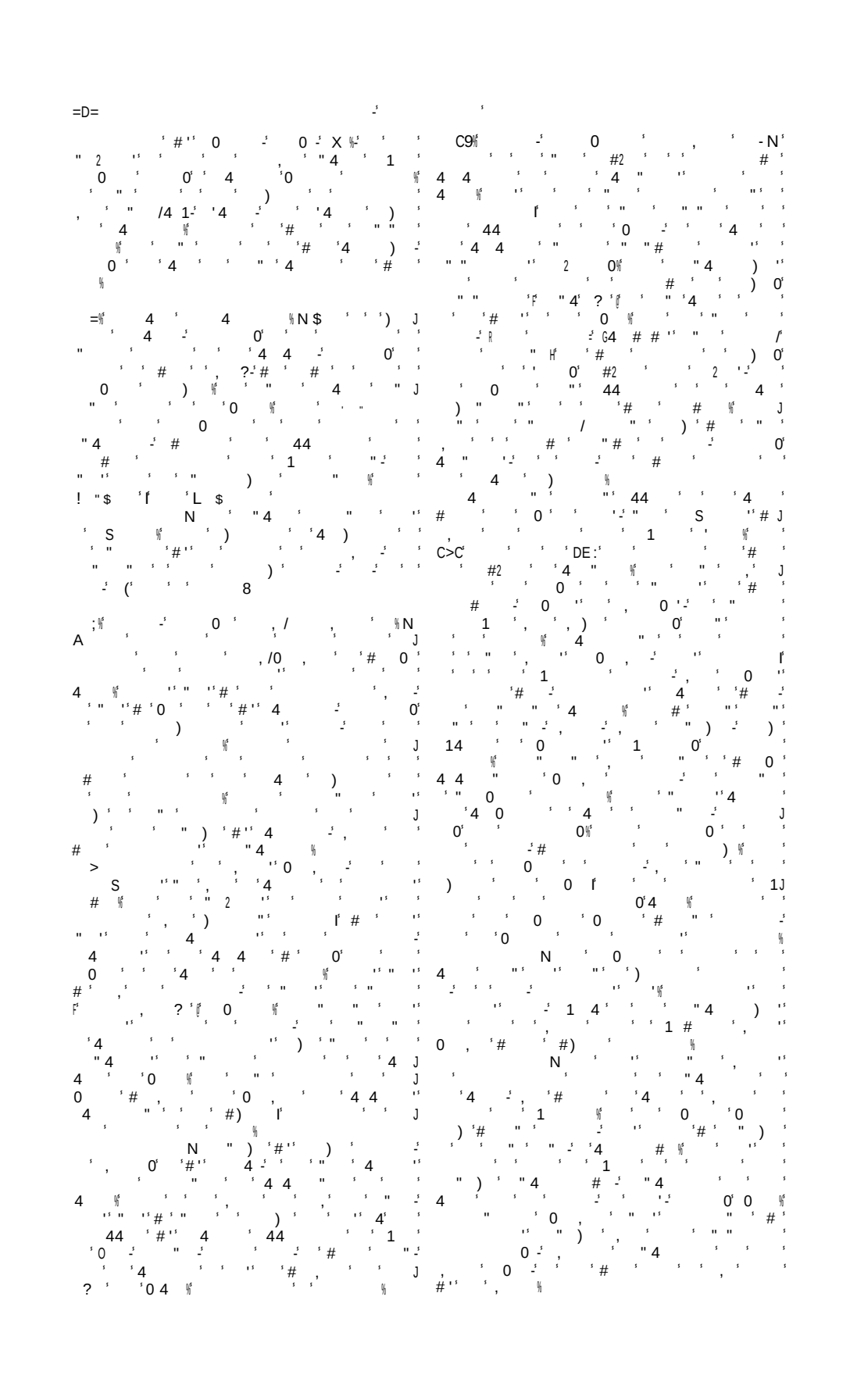

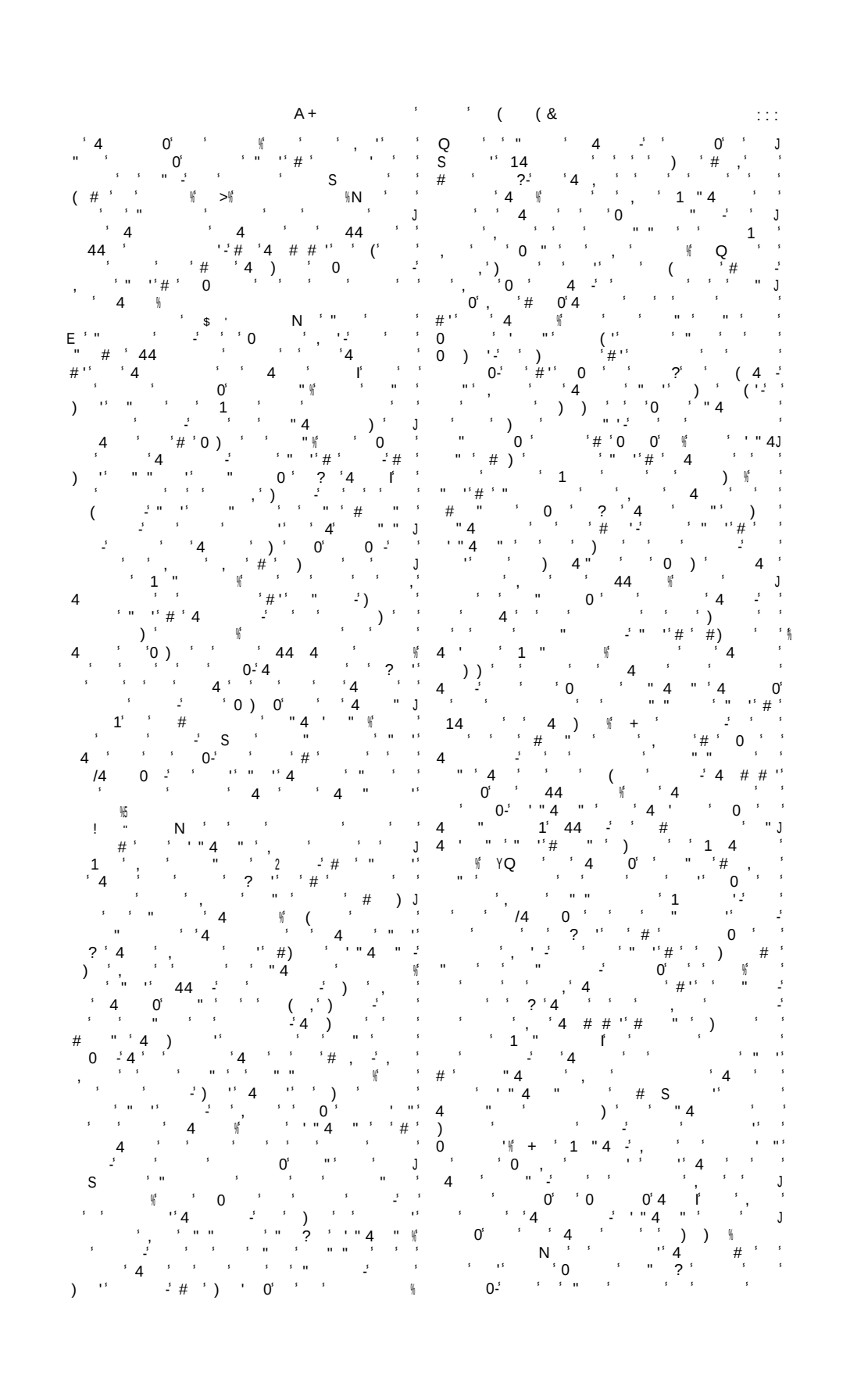

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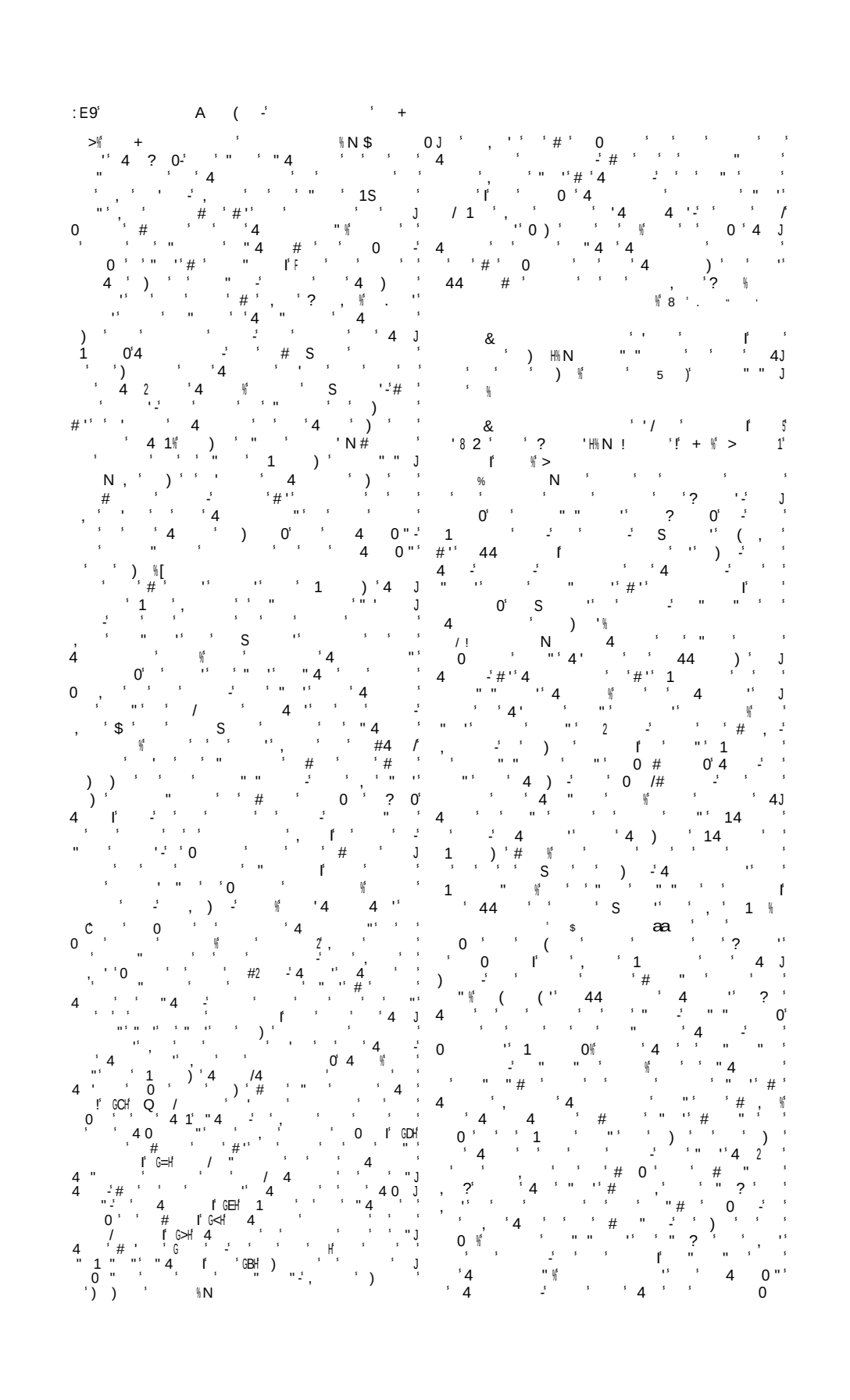

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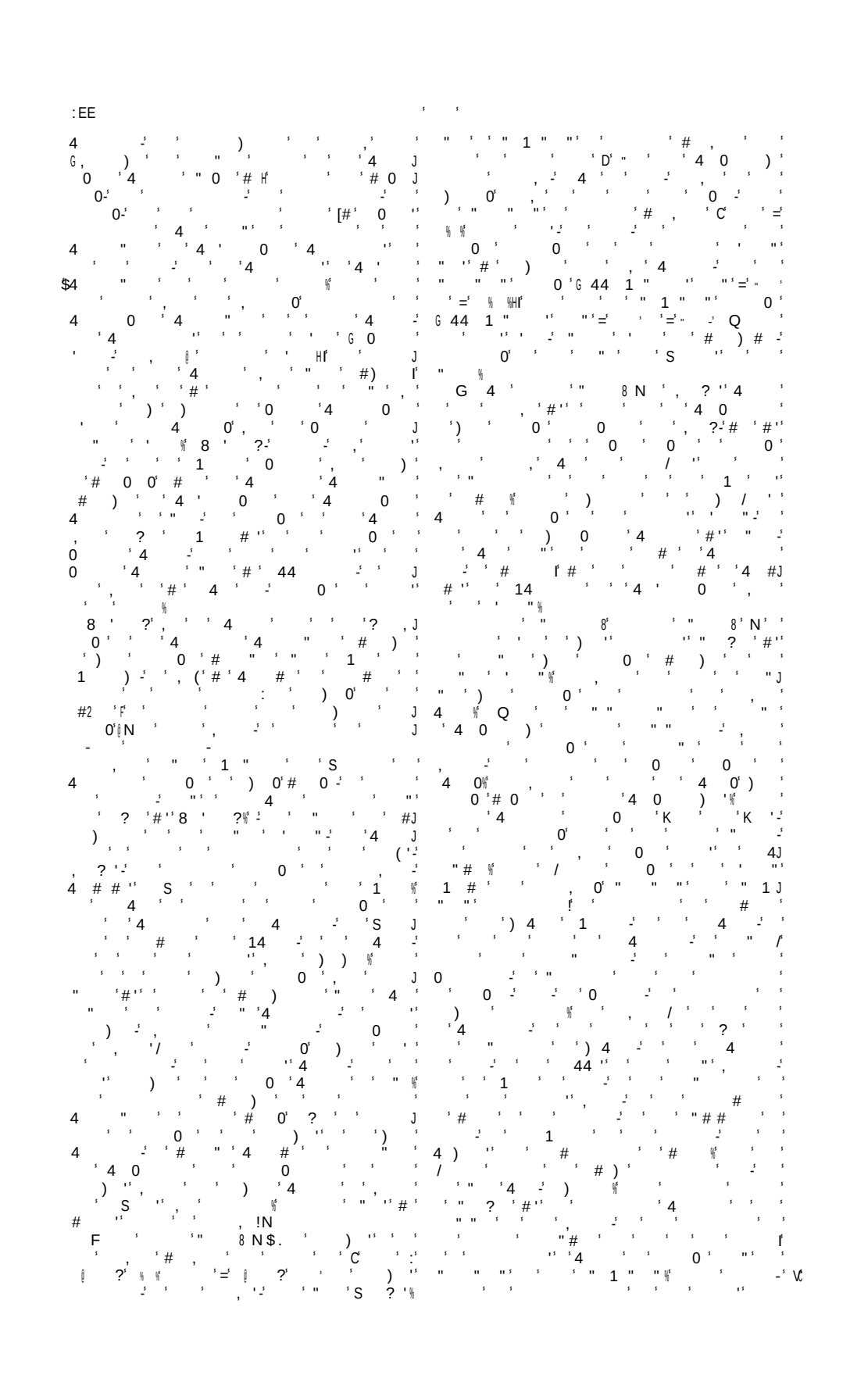

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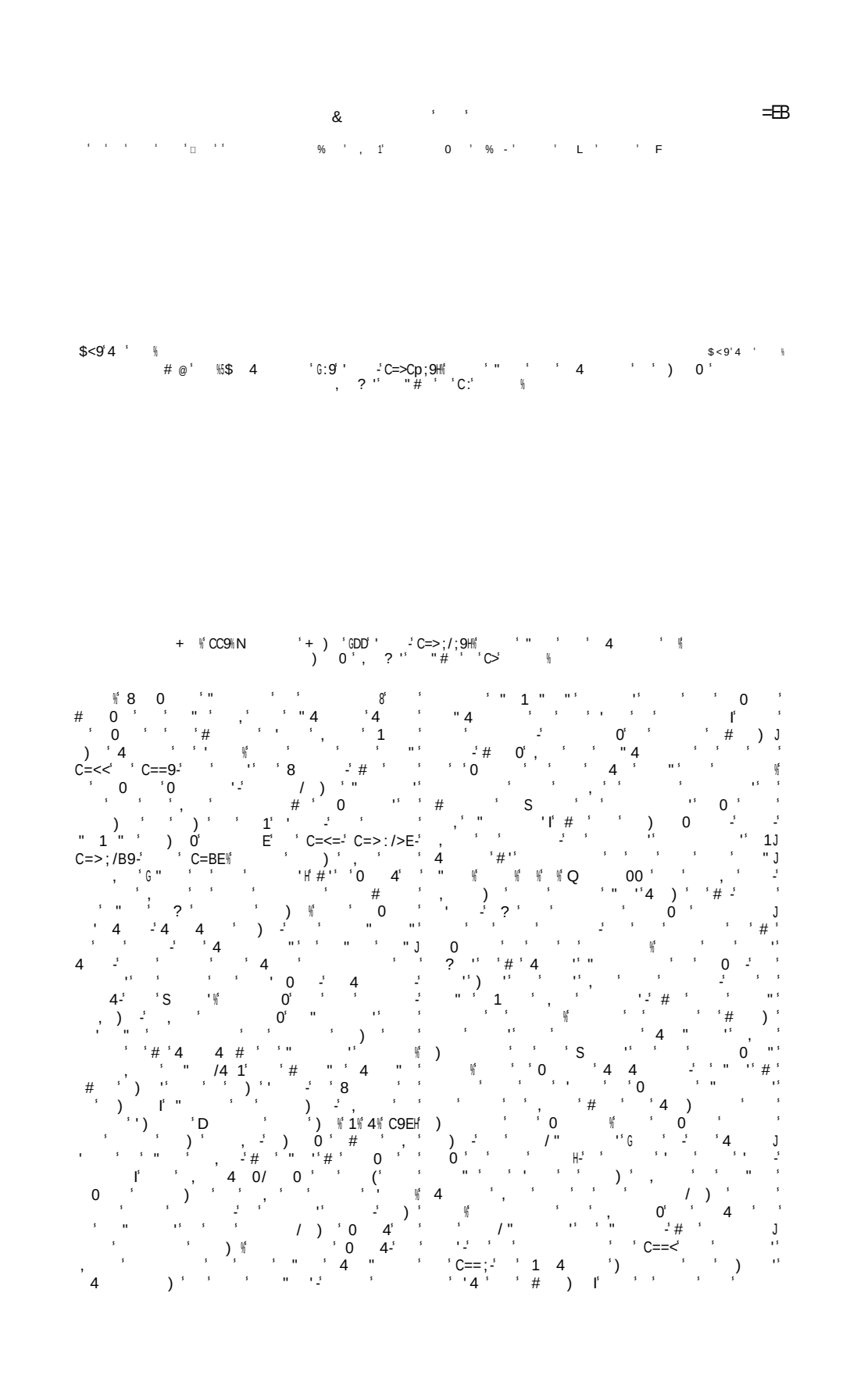

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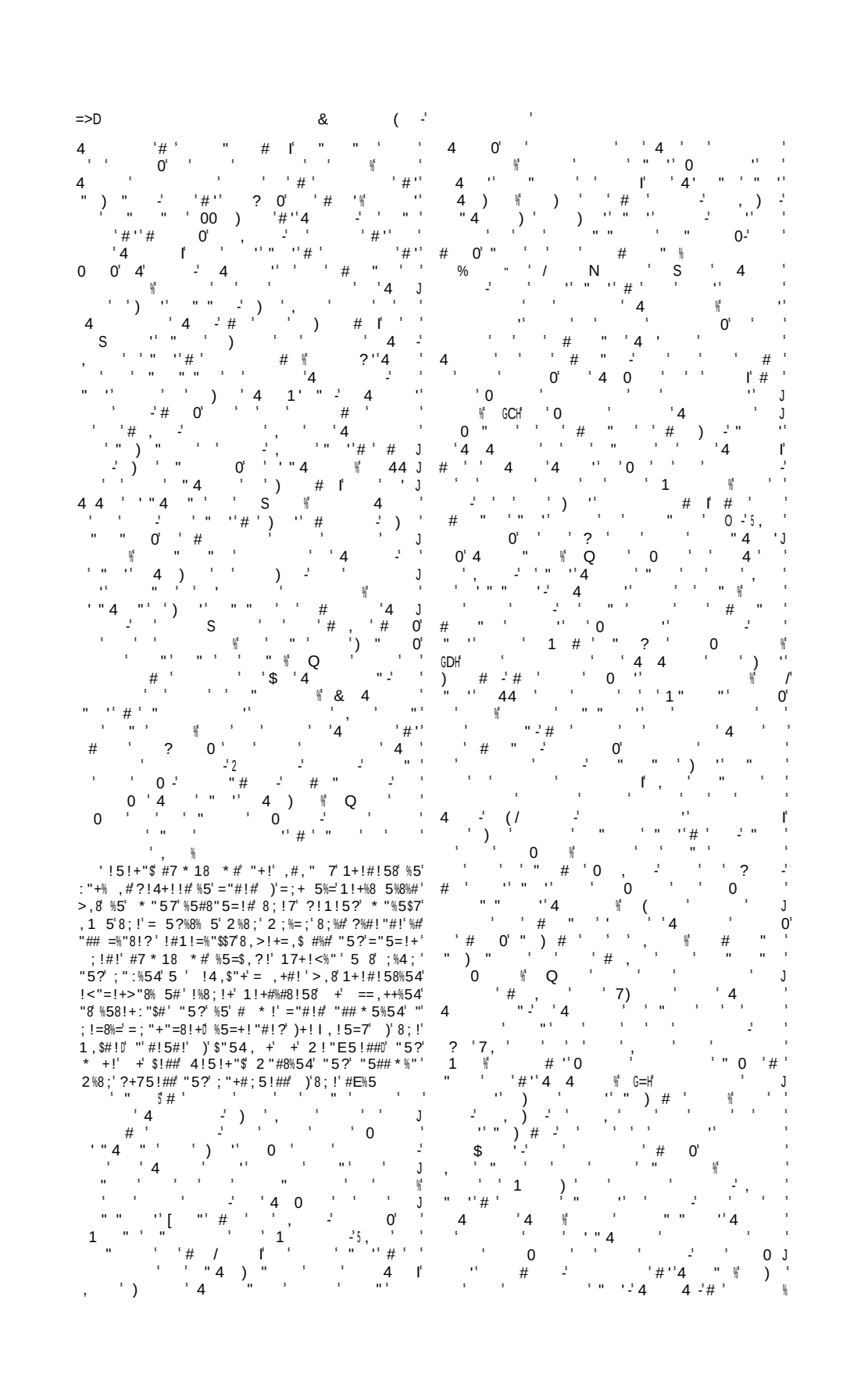

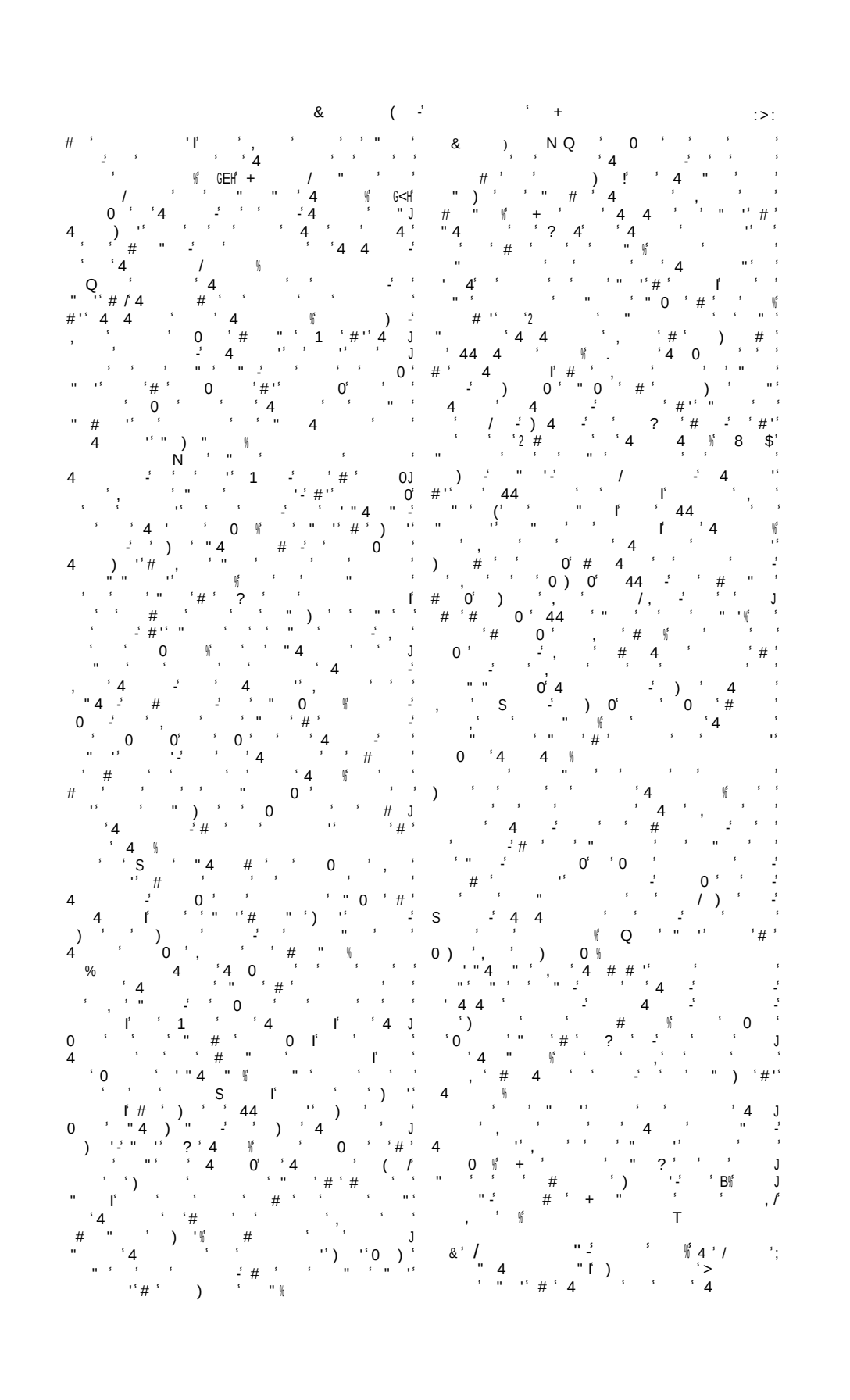

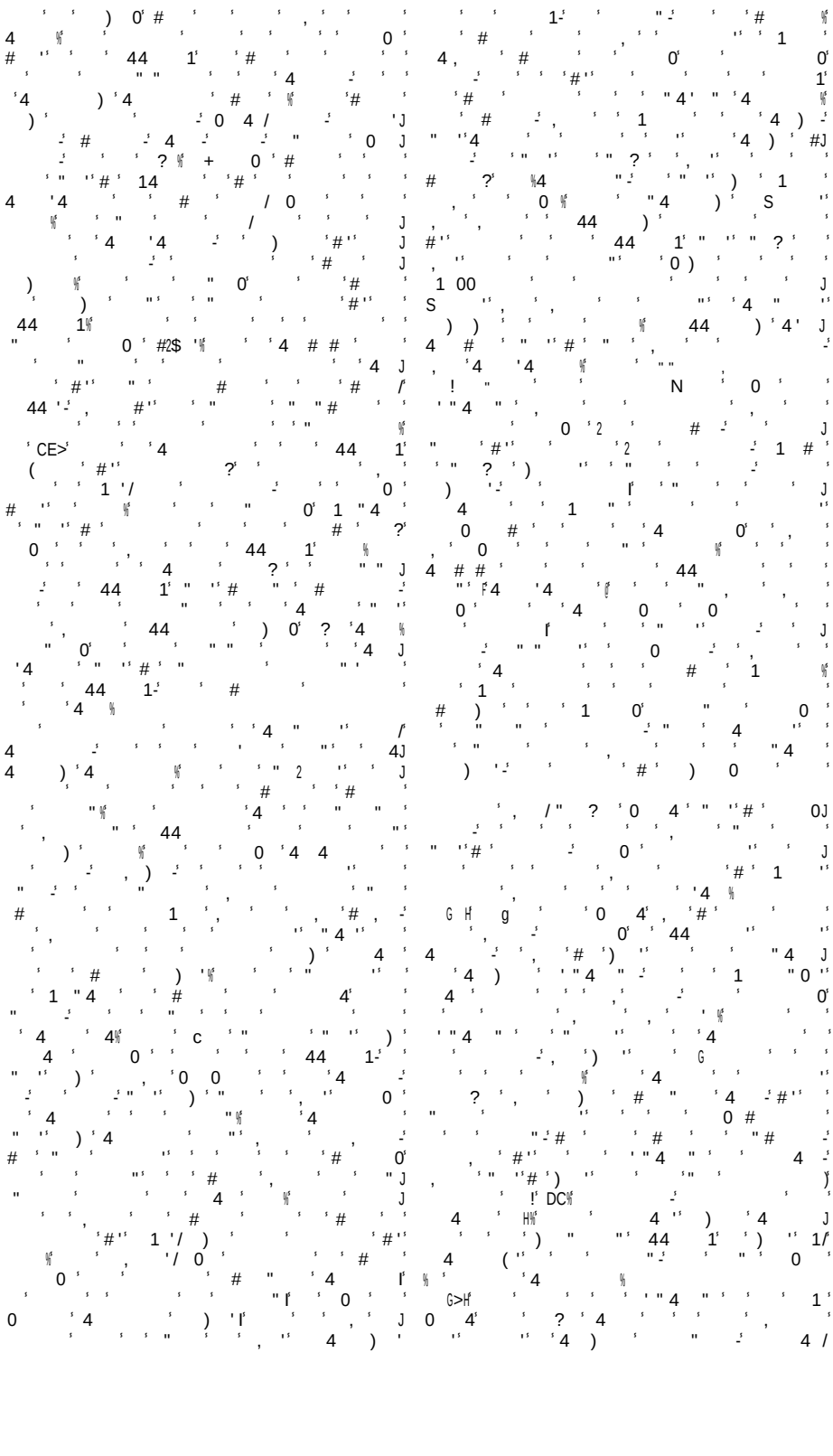

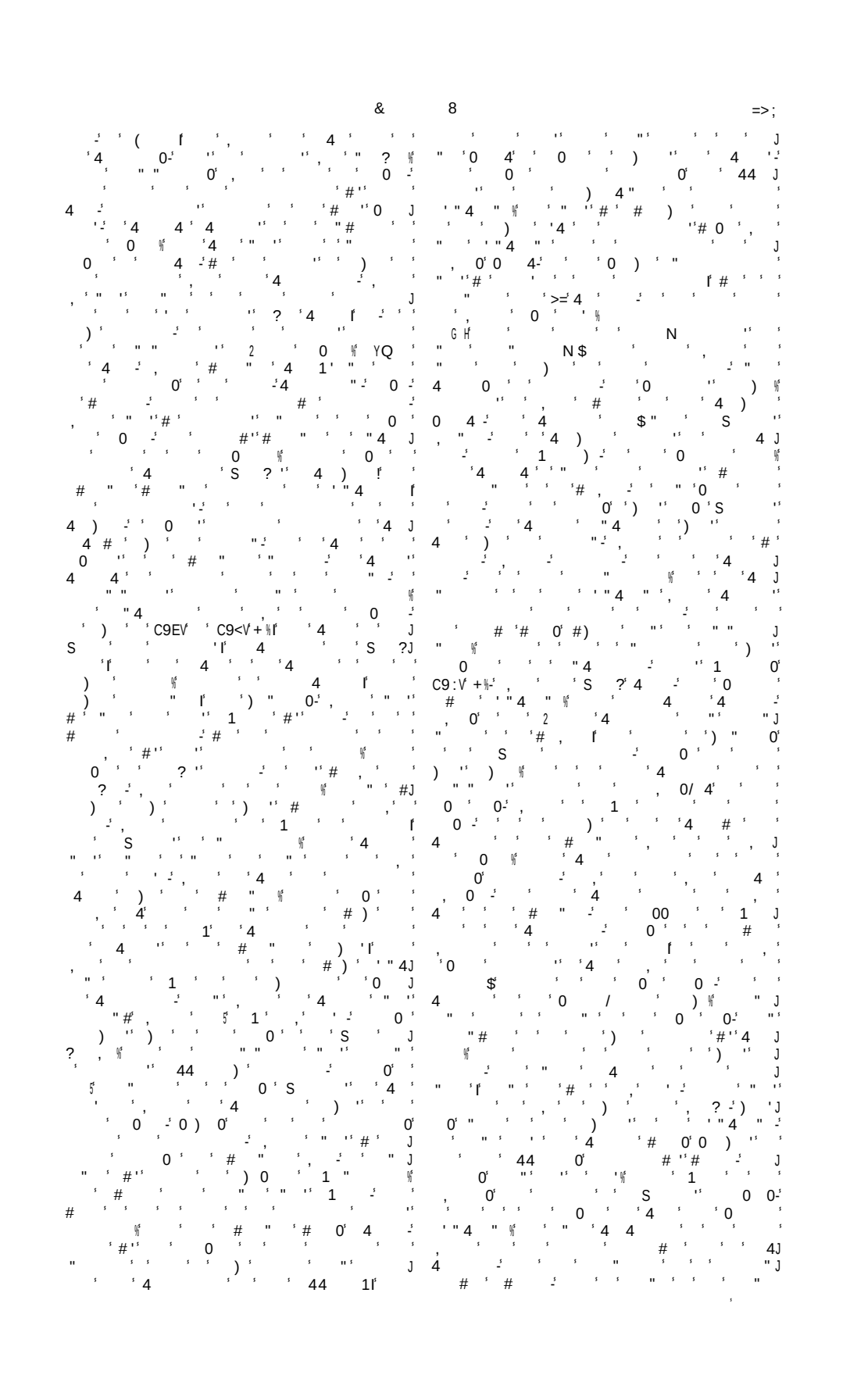

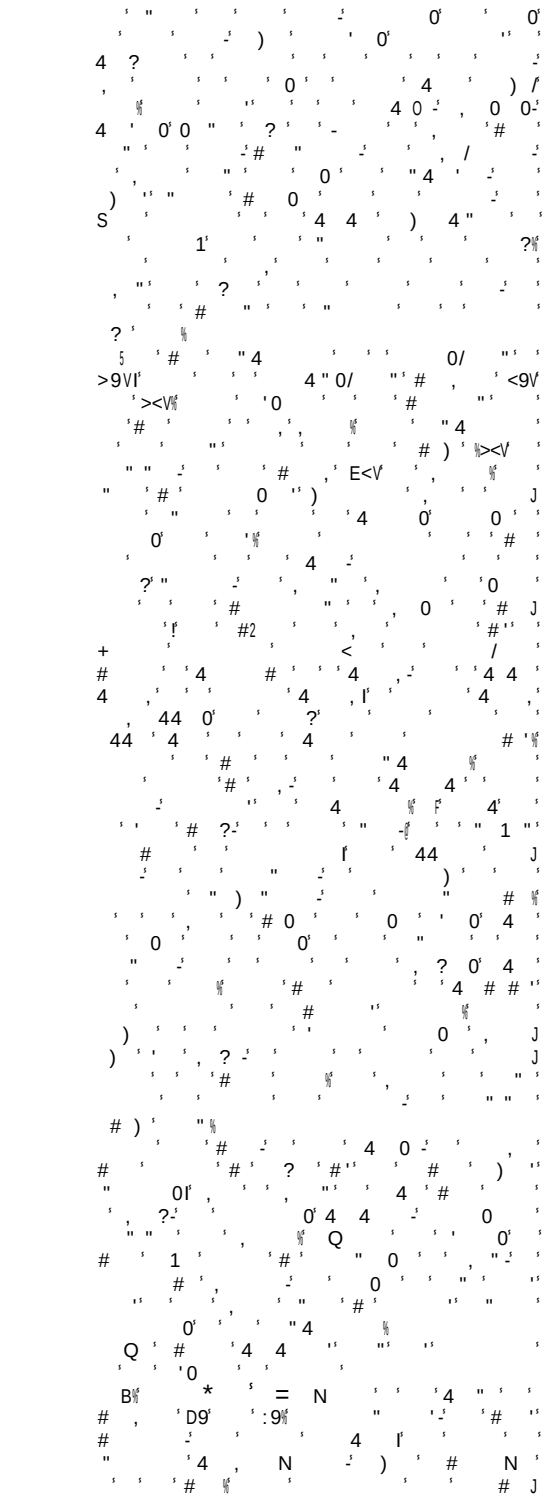

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digestion of the organism. Some of the Cœlenterata possess no mesoderm, and in these, Hydra, for example, the endodermic cells, which have the property of sending out amœboid processes and of performing the normal digestion of the organism, play the *rôle* of phagocytes; in other similar animals, the ectoderm cells are also phagocytes. Such animals are without any vascular system. This is also absent in the Medusæ, which, however, possess a mesoderm differing from that of the sponges in the fact that the mesodermic cells play no part in the normal digestion of the animal. These mesodermic cells are, however, the phagocytes. They surround and attack harmful substances introduced into the substance of the animal, and may unite together, forming *plasmodes*, an example of the formation of giant-cells low down in the animal scale. In all animals higher than the medusæ, namely, echinoderms, worms, vertebrates, &c., this formation of plasmodes, or giant-cells, by the union of mesodermic cells is very common, the plasmode in some instances completely surrounding the foreign body or parasite, as in fig. 117.

FIG. 117.—A Giant-cell enclosing the clubs of the fungus in Actinomycosis. (Verick, Oc. $1 \times \frac{1}{12} = 700$ diam.) From a preparation and drawing by Dr. Armand Ruffer.

The classes of Mollusca and Arthropoda possess a vascular system, filled with a liquid containing colourless cells. These cells are mononuclear; their protoplasm is in one variety granular, in another hyaline. They act as the phagocytes of the animal. Numerous experiments have shown that, after a lesion of a part of the animal, these cells accumulate near the injured spot as they do in an 'inflamed' area in warm-blooded animals. A similar accumulation occurs around inert foreign bodies introduced into the animal; and the cells also take up pigment-granules injected into the tissues (Haeckel, 1862). The best example of infection in such animals has been brought forward by Metchnikoff as occurring in the water-flea, *Daphnia magna*, which in a pond was found infested with a kind of yeast-fungus, *Monospora bicuspidata*. At certain periods an epidemic of this disease will kill off nearly all the daphne in the pond. A study of the process shows that the ripe spores of the fungus are eaten by the daphne, and pass through the intestinal wall into the body cavity. Here the elongated spores become surrounded by the leucocytes, and one of two events may happen. The spores may rapidly increase in number and fill the body cavity, eventually destroying the life of the daphnia; or, becoming surrounded by leucocytes, they undergo degeneration, so that they are killed or are not fatal to the daphnia.

FIG. 118.—A phagocyte of the Daphnia containing two undegenerated spores of the Monospora. (Metchnikoff, Virchow's *Archiv*, vol. xcvi.)

FIG. 119.—A spore of the Monospora enclosed by phagocytes, and undergoing degeneration. (Metchnikoff, *ibid.*)

In both cases there is a struggle between the leucocytes and the germinating fungus: in the first, the fungus overcomes the resistance of the leucocytes; in the second, the leucocytes surround and finally digest the spores of the fungus.

In the very young tadpoles of the lower amphibia (urodeles) phenomena similar to those occurring in mollusca have been observed by Metchnikoff and others. Thus, after a slight injury to the non-vascular fin of the tadpole, the amœboid cells collect at the injured spot, the fixed cells of the tissue taking no part in the process. In older tadpoles, when the blood-vessels are developed in the fin, there is still this accumulation of amœboid cells at the injured spot; but there are also the phenomena of inflammation such as are observed in the higher animals, namely, acceleration of the blood-stream, &c. As Metchnikoff points out, both the phenomena in the very young and those in the older tadpole must be classed as 'inflammatory,' although in one case there is no vascular change. Similarly, the phenomena following an injury or an infection which have been described as occurring in invertebrate animals possessing a mesoderm must be classed as inflammatory; not as belonging to a completely developed process of inflammation, but as forming one of the stages in the evolution of the inflammatory process in the animal kingdom.

Phagocytosis in the *higher animals* is a part of inflammatory and of infective processes. It is a question whether all primary inflammatory processes are not infective, that is, due to a living infective agent; it is probable that they are. The study of the nature of inflammation and of the process of infection are in reality to be conducted on the same lines, namely, that both are due to the introduction into the healthy organism of a harmful agency, which may either remain localised in its action, or may become generalised.

The cells which act as phagocytes are derived from the middle layer of the embryo (mesoderm), and are some varieties of leuco-

cytes, the endothelial cells of the vessels, and the elements of the splenic pulp. The endothelial cells possess the power of contractility in many animals. In leprosy they not uncommonly contain large masses of the bacillus lepræ. In rabbits inoculated intravenously with the bacillus tuberculosis, these cells take up the bacillus; a similar phagocytosis occurs in swine-erysipelas. The endothelial cells and the elements of the splenic pulp are also macrophages, which will be described immediately.

Varieties of Leucocytes.—There are four chief varieties of leucocytes which exist in the blood and lymph of vertebrate animals.

1. *Lymphocytes*, characterised by the presence of a single round nucleus, surrounded by a thin layer of protoplasm, which is stained slightly by aniline dyes, while the nucleus is deeply coloured (fig. 120, *a*).

FIG. 120.—*a*. Lymphocyte. *b*. Mononuclear leucocyte.

2. *Mononuclear leucocytes — Macrophages.*—These also possess a single nucleus, but the protoplasm surrounding it is greater in quantity than in the lymphocytes; both nucleus and protoplasm are well stained by aniline dyes (fig. 120, *b*).

3. *Eosinophile leucocytes* (Ehrlich).—These possess a lobed nucleus, but are characterised chiefly by the characters of the surrounding protoplasm, which contains large granules stained only by acid aniline dyes (such as eosin), and not by the alkaline ones (such as methylene blue, basic fuchsin, &c.) They are formed in the bone-marrow (fig. 121, *a*).

4. *Polynuclear* or *Neutrophile leucocytes—Microphages.*—These possess either a lobed nucleus or several nuclei, sometimes joined by filaments; the form of nucleus or nuclei is very varied. They have been

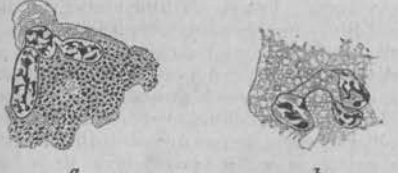


FIG. 121.—*a*. Eosinophile leucocyte. *b*. Polynuclear leucocyte. (Quain's *Anatomy*, 10th ed. by permission of Professor Schäfer.)

termed neutrophile because the granules of the protoplasm are only stained by a mixture of acid and alkaline aniline dyes. The neutrophile leucocytes are found only in man; in other mammals (such as the rabbit and guinea-pig) their place is taken by the amphophile or pseudo-eosinophile leucocytes (fig. 121, *b*).

They are by far the most numerous of the varieties of leucocytes, forming three-fourths of the total number.

Of these varieties only the mononuclear and the neutrophile leucocytes act as phagocytes; and the former may also engulph the neutrophile leucocytes when these are dead or dying.

Leucocytes can digest suitable particles taken into their substance. Their digestive power is a property inherent in all original cells. In some cases of infective disease, the living bacteria have been observed to undergo this digestion in the phagocyte; they lose their protoplasm, leaving the investing membrane, which also finally disappears; and they also lose the property of being stained by some aniline dyes, such as vesuvine. Examples of this are found in recurrent fever in the ape, and in the streptococcus erysipelatis in man (Metchnikoff). Some of the bacteria may be digested and others not, the latter infecting the organism generally. This has been observed in tuberculosis and in swine-erysipelas.

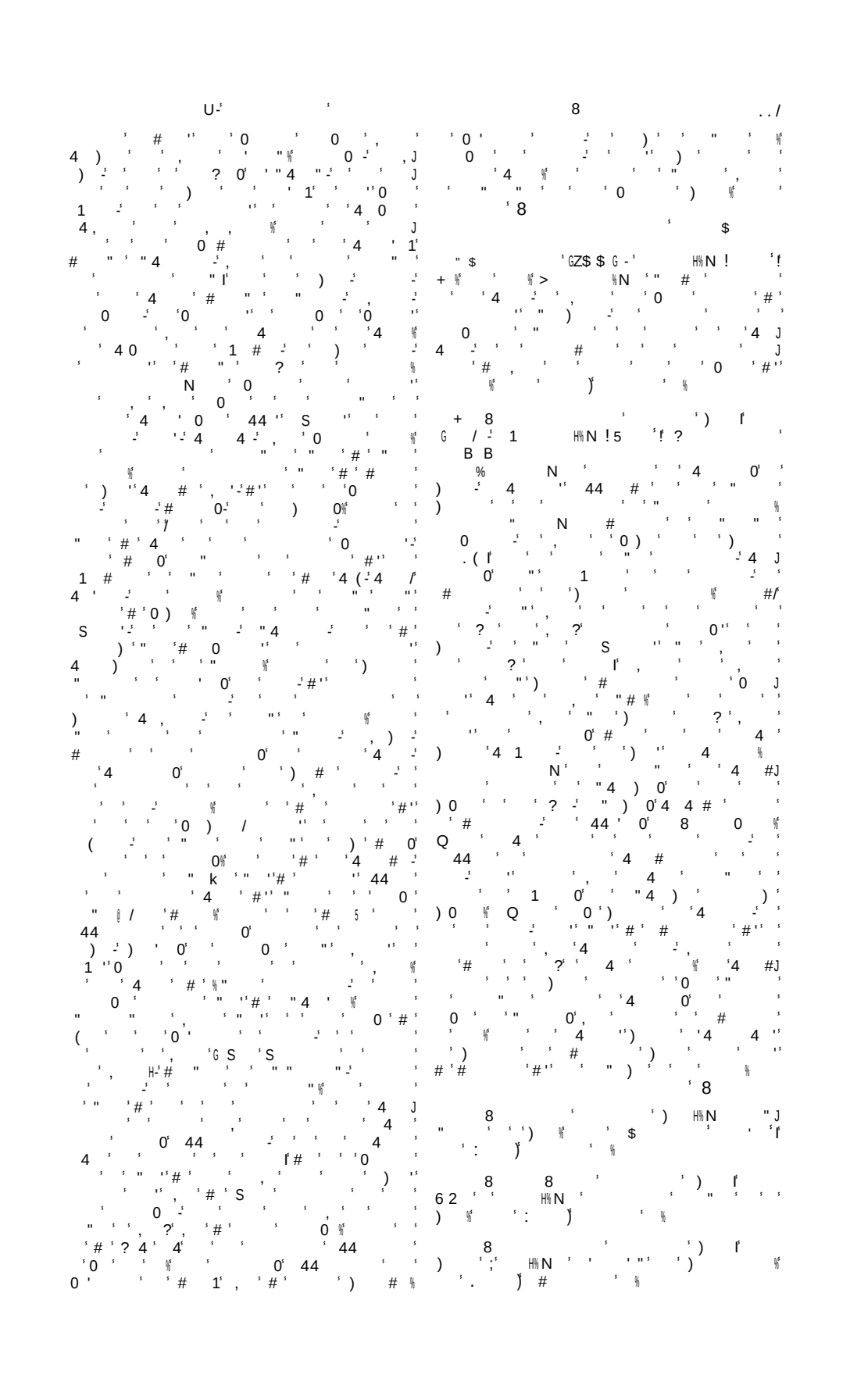
It has been a question whether the bacteria taken in are living or not; but it has been proved by Metchnikoff that they are in many cases not only living, but virulent, since a single phagocyte of a pigeon (an animal refractory to anthrax) containing anthrax bacilli has been separated, and the bacilli cultivated in a suitable medium, proving on inoculation fatal to mice, &c.

The two varieties of leucocytes which act as phagocytes appear in some instances to be selective in their action. Thus in man it is the neutrophile leucocyte which takes in the streptococcus erysipelatis and the gonococcus; the mononuclear leucocyte remaining inactive. On the other hand, the mononuclear leucocyte is the phagocyte of the bacillus lepræ; the neutrophile variety remaining inactive.

Instead of digesting the bacterium, the phagocyte may prevent it developing. Thus the spores of anthrax injected into fowls and frogs (which are refractory to the disease) commence to germinate, but are taken up by the leucocytes. If, however, the body-temperature of the fowl be lowered by cooling the animal, or that of the frog increased by warming, the activity of the leucocytes is diminished, and the spores then germinate rapidly, the bacilli invading the whole body.

In other cases the leucocytes do not take in the infective agent, as in mice and guinea-pigs infected with anthrax, and in pigeons and rabbits infected with fowl-cholera; and according to Metchnikoff the more virulent the infection, the less phagocytosis occurs.

Why the leucocyte, possessing as it does the property of absorbing solid particles, refuses in one instance to act as a phagocyte,



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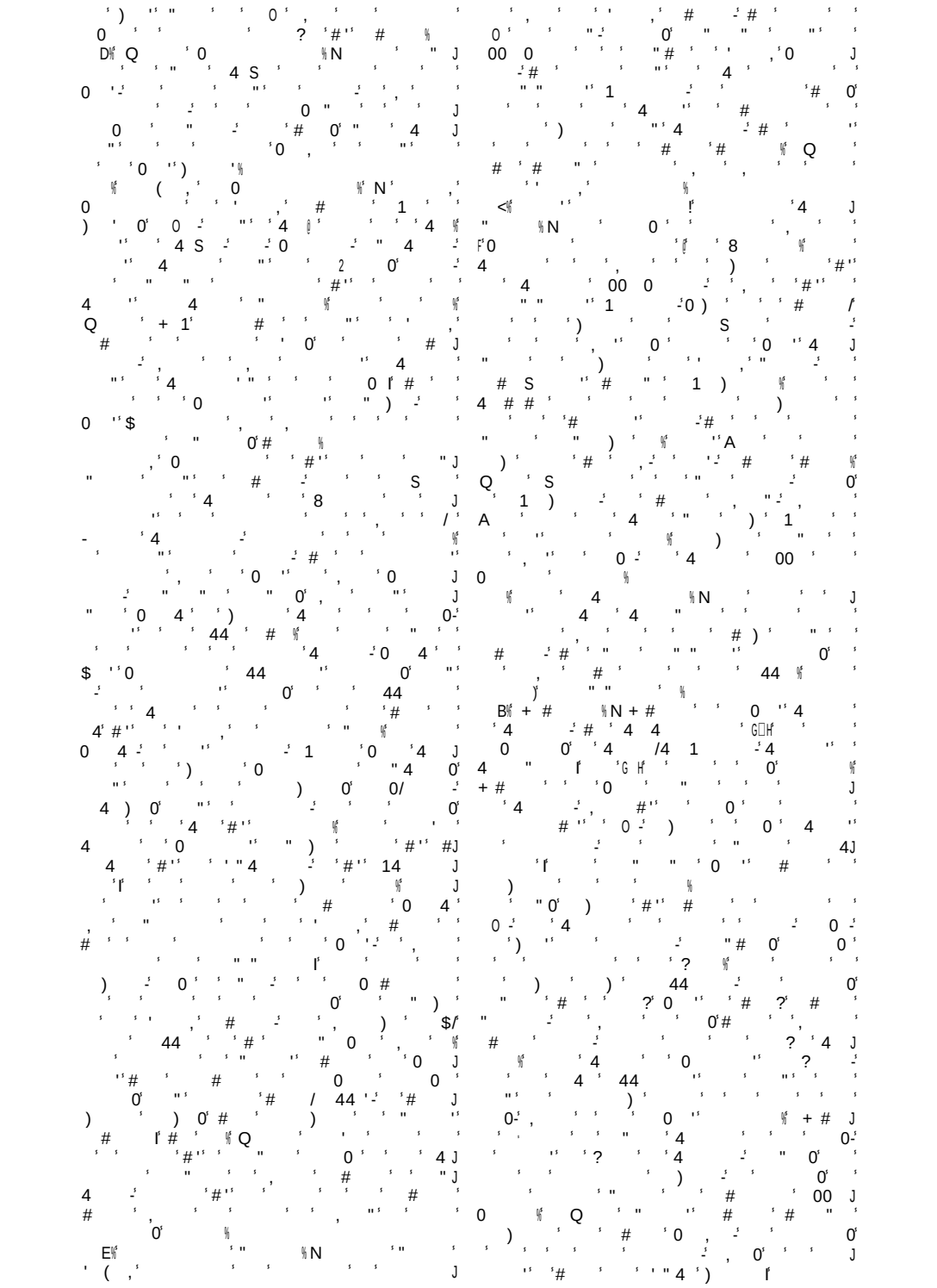

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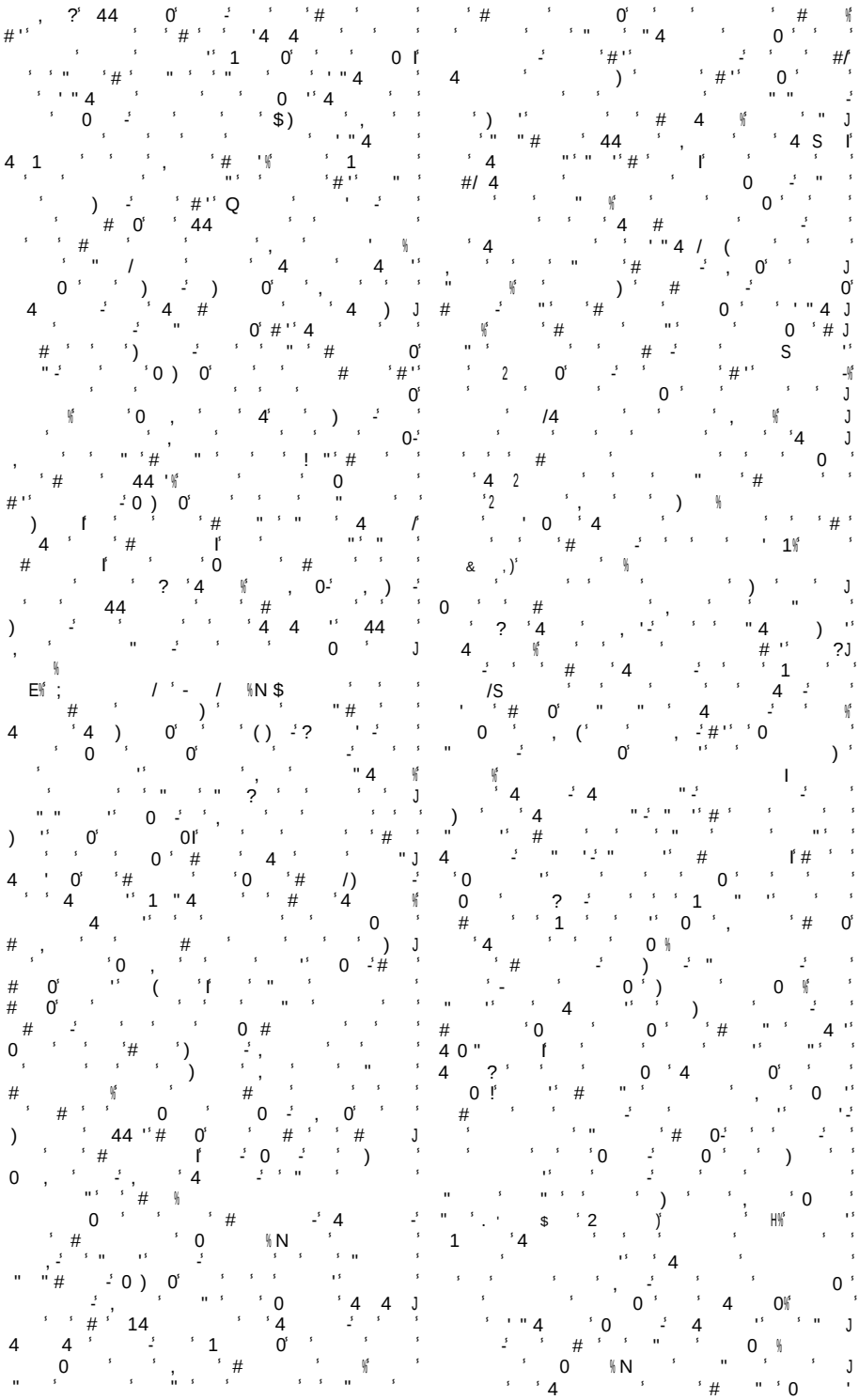

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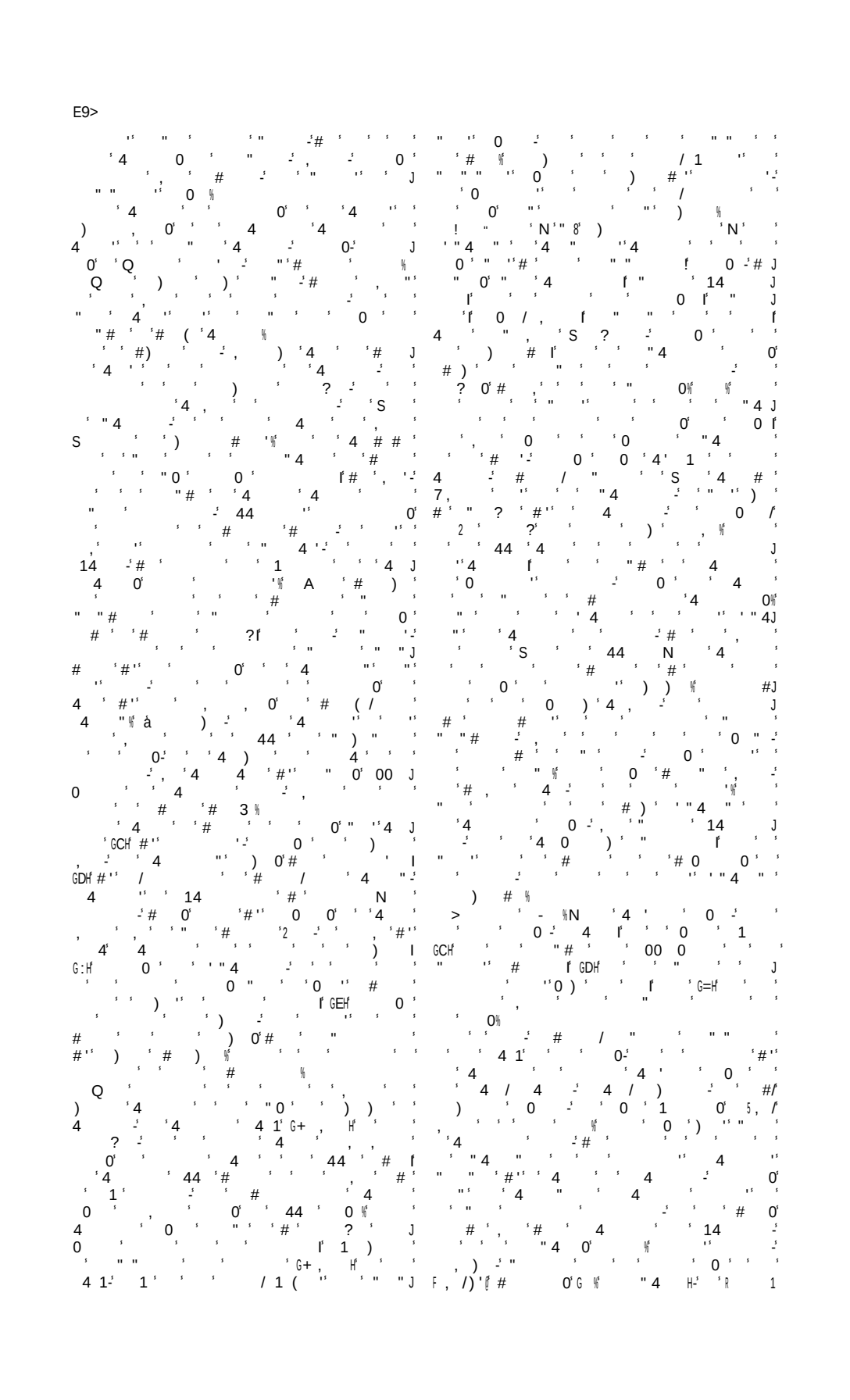

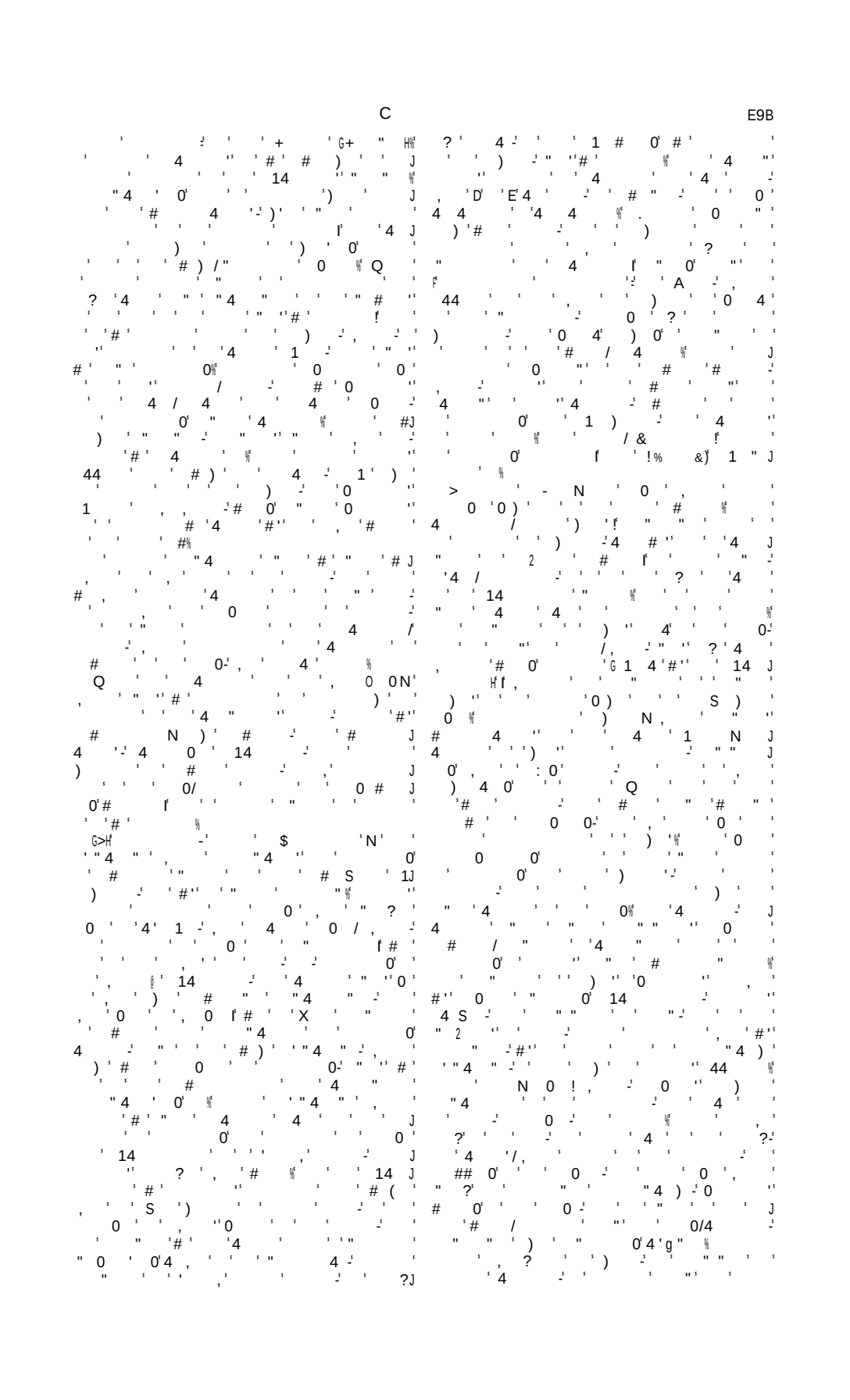

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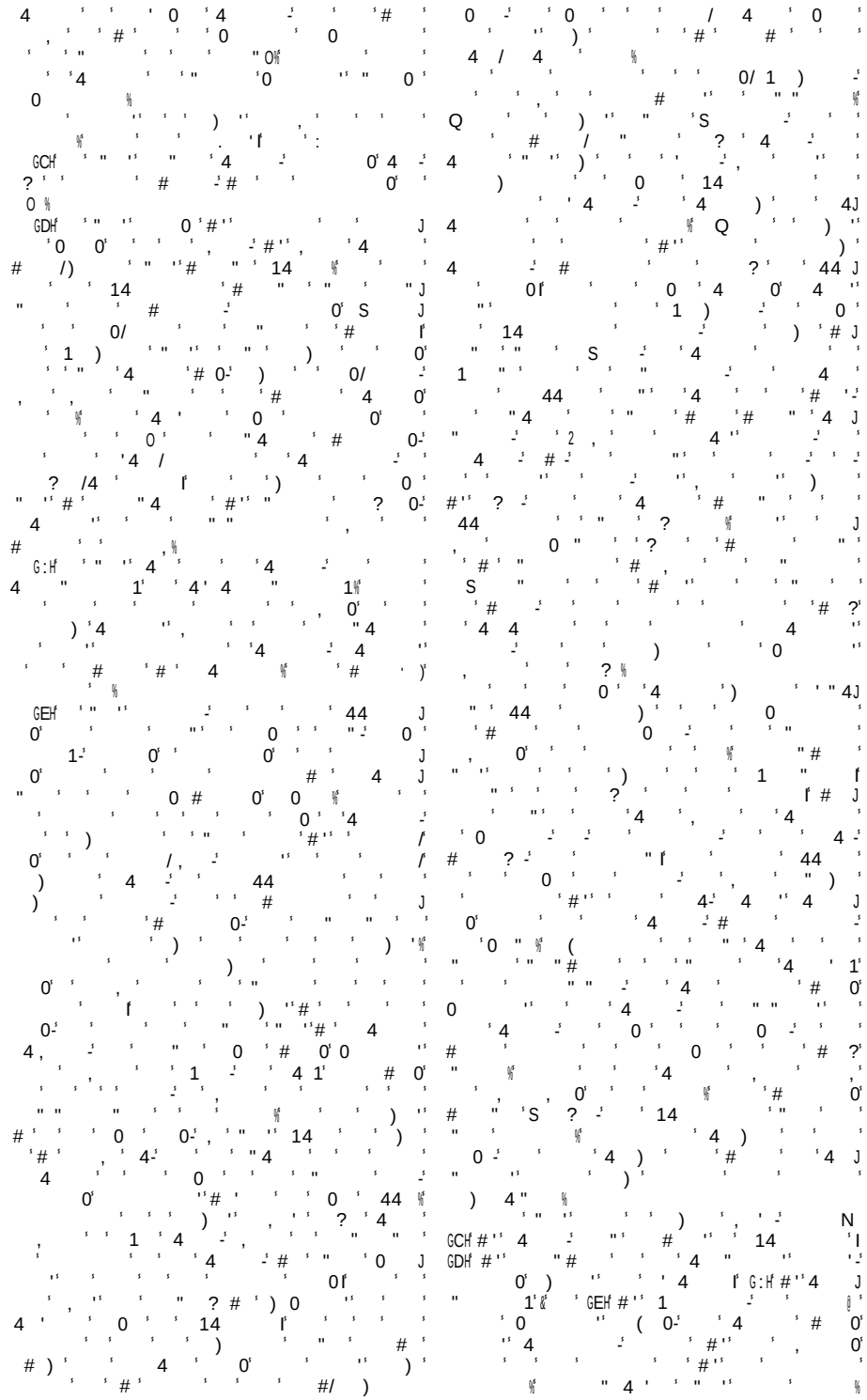

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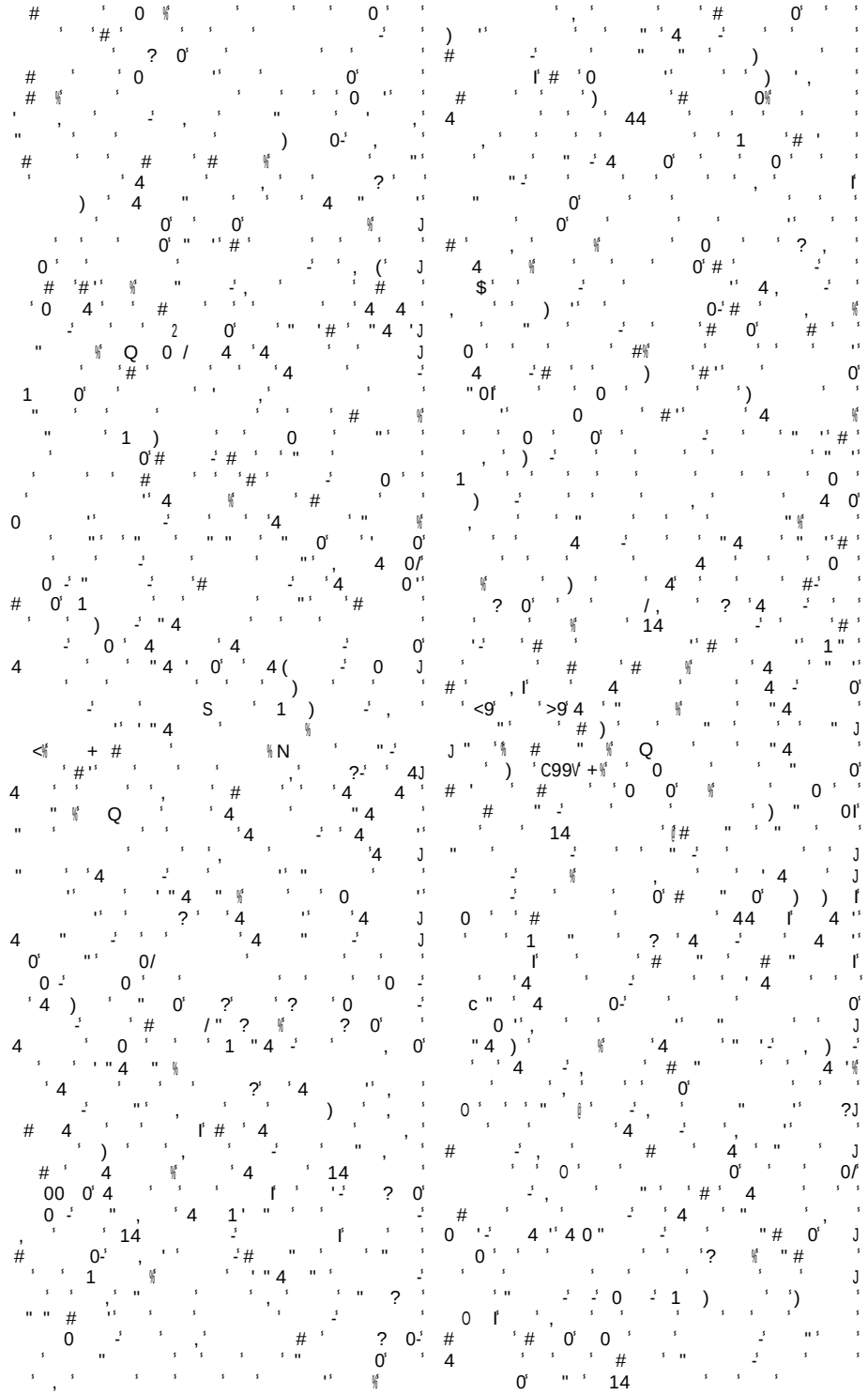

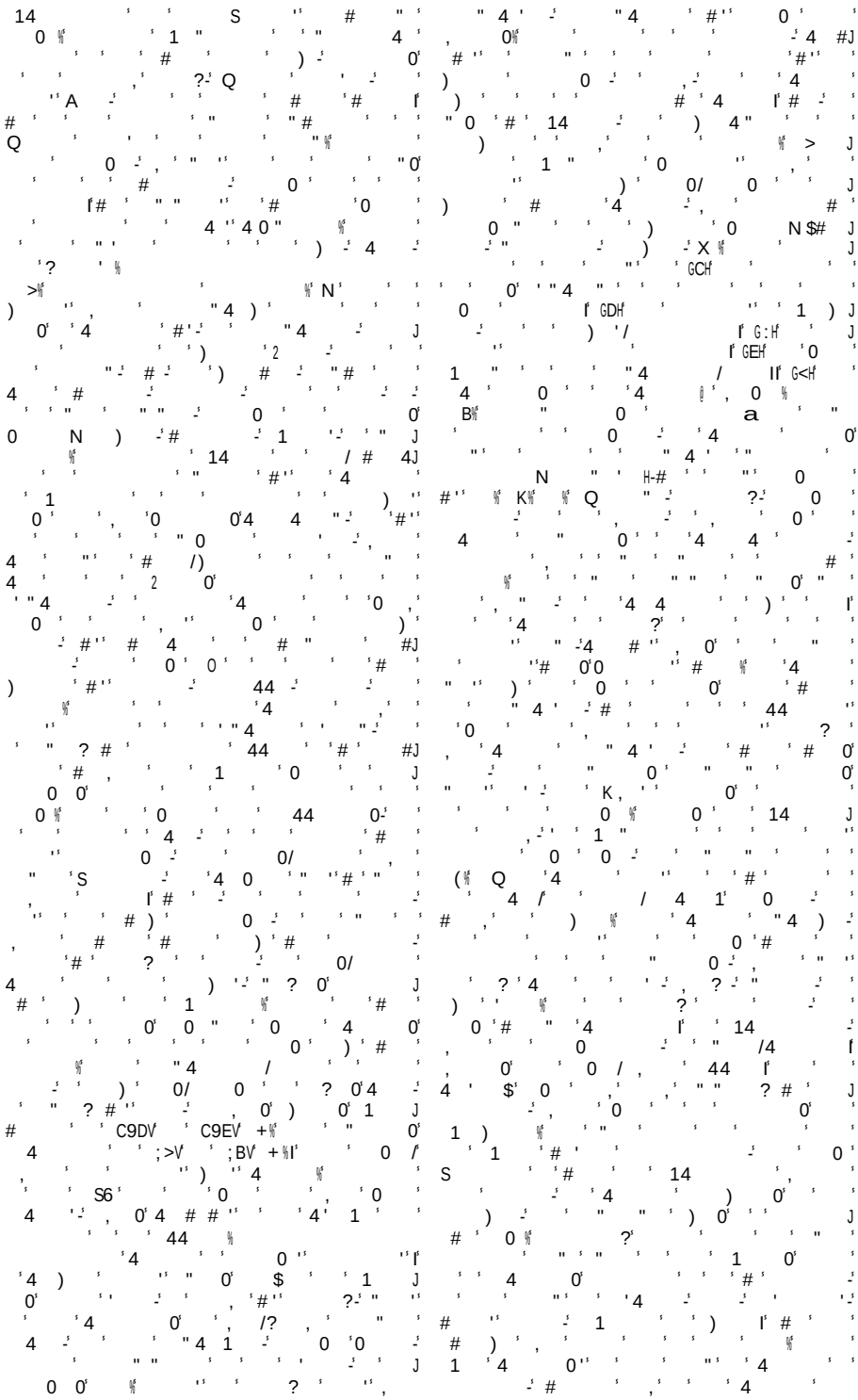

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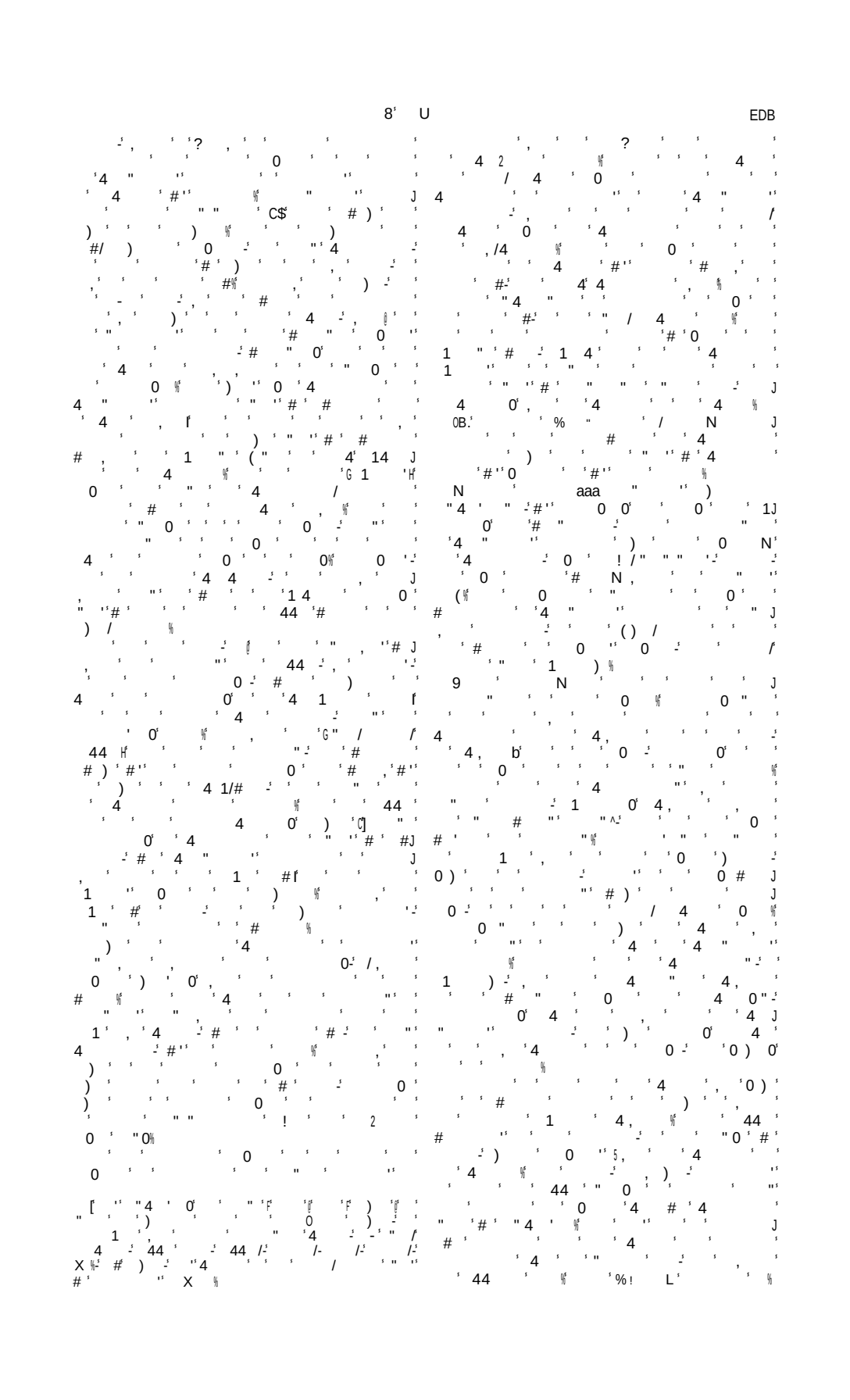

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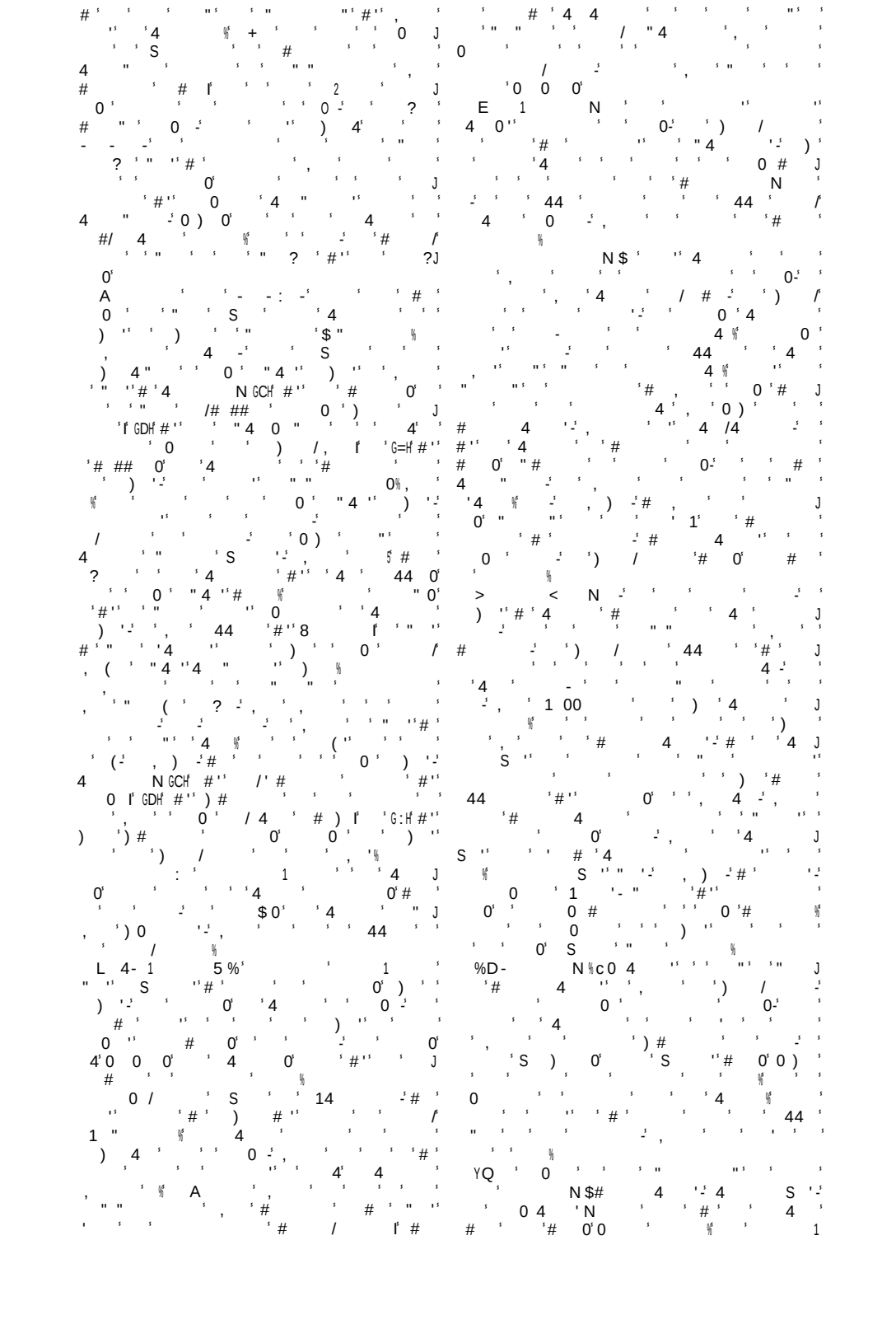

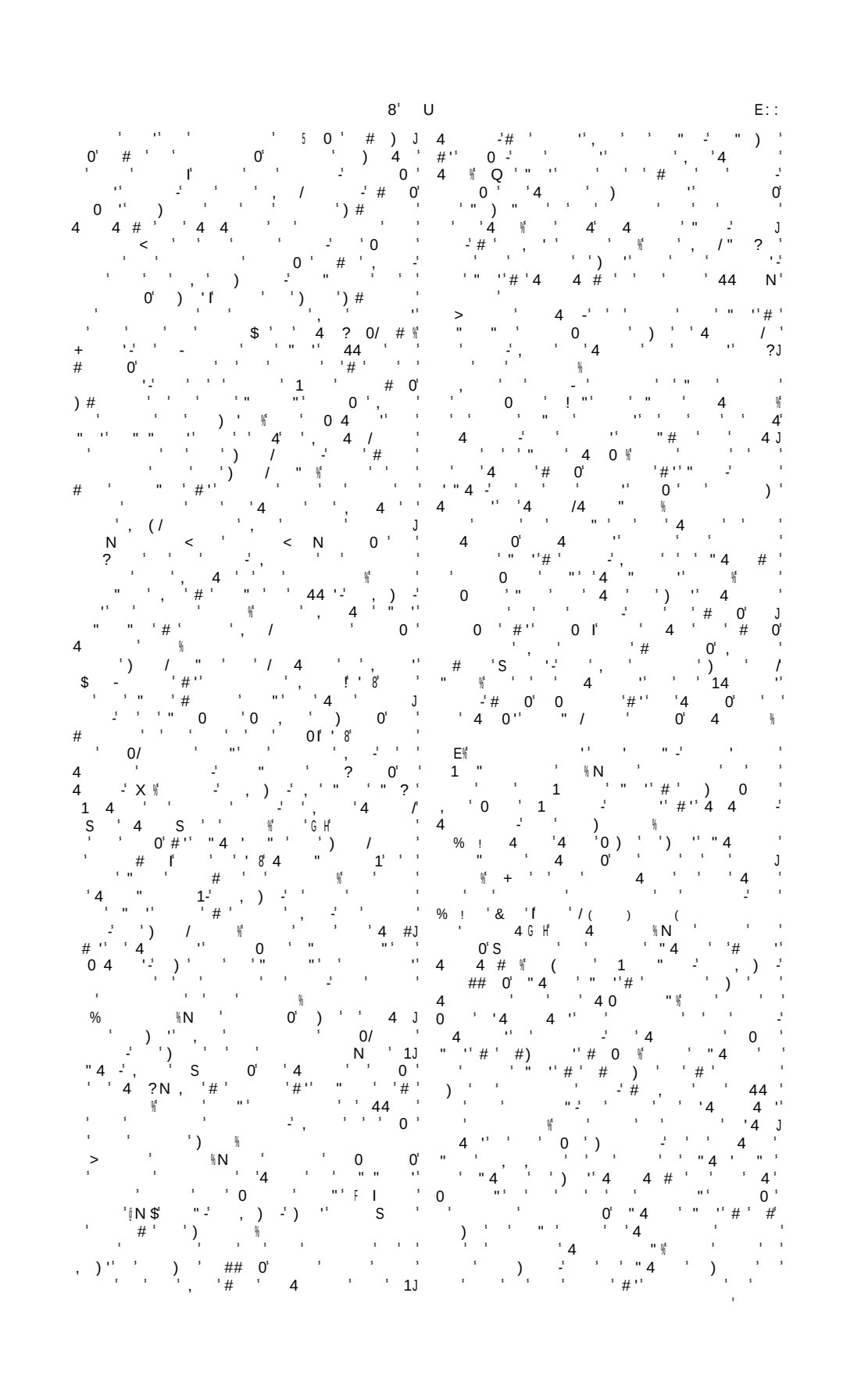

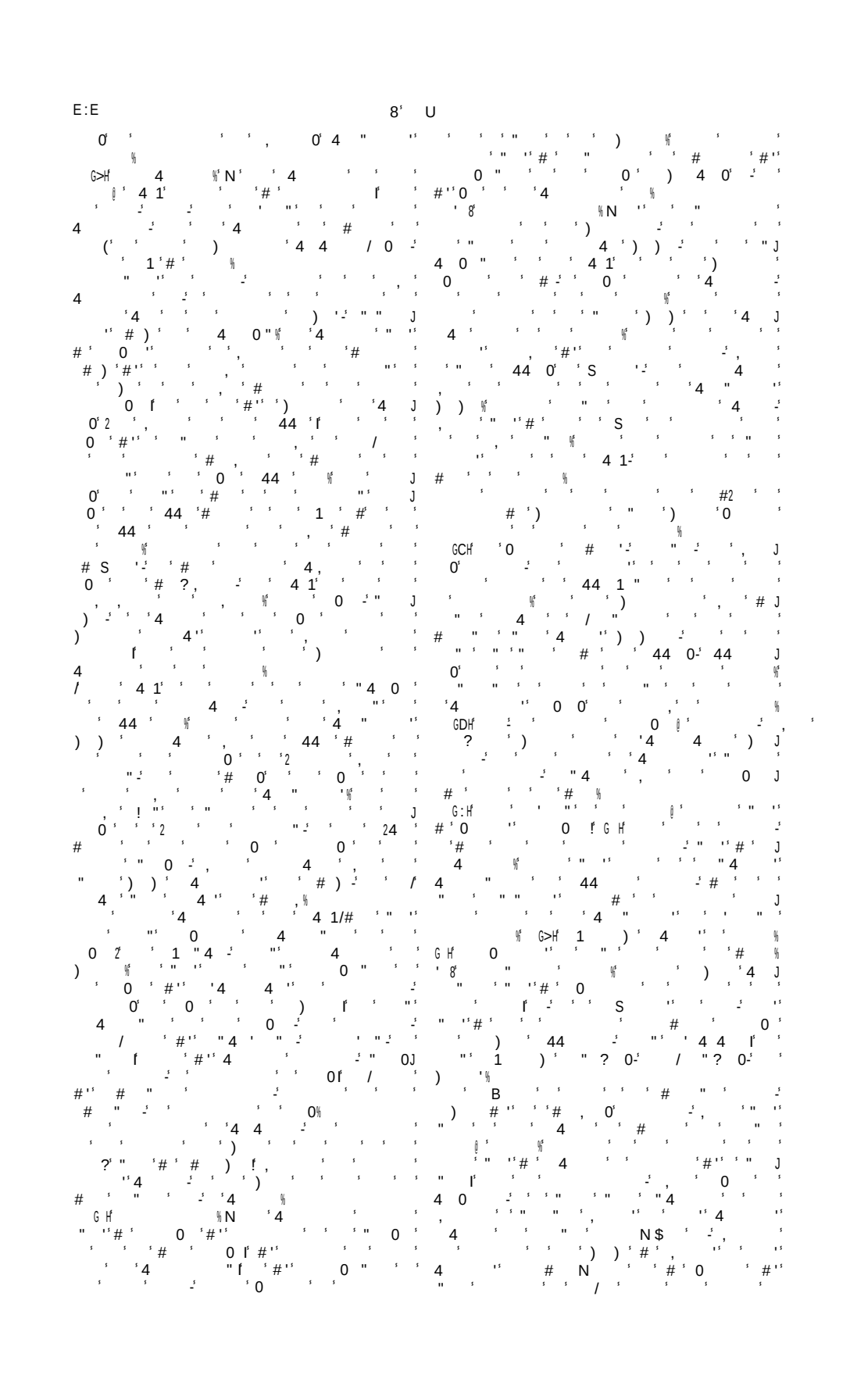

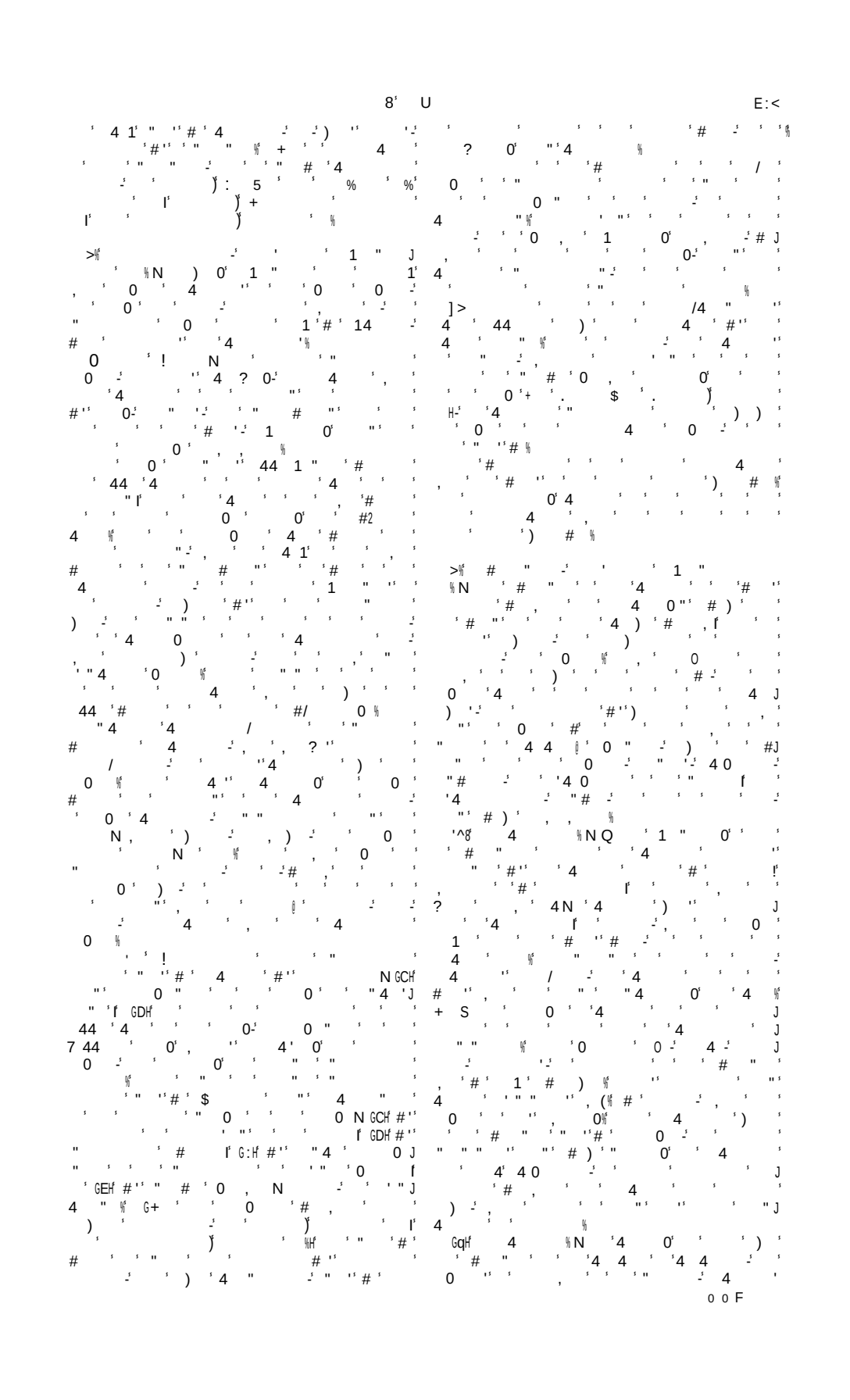

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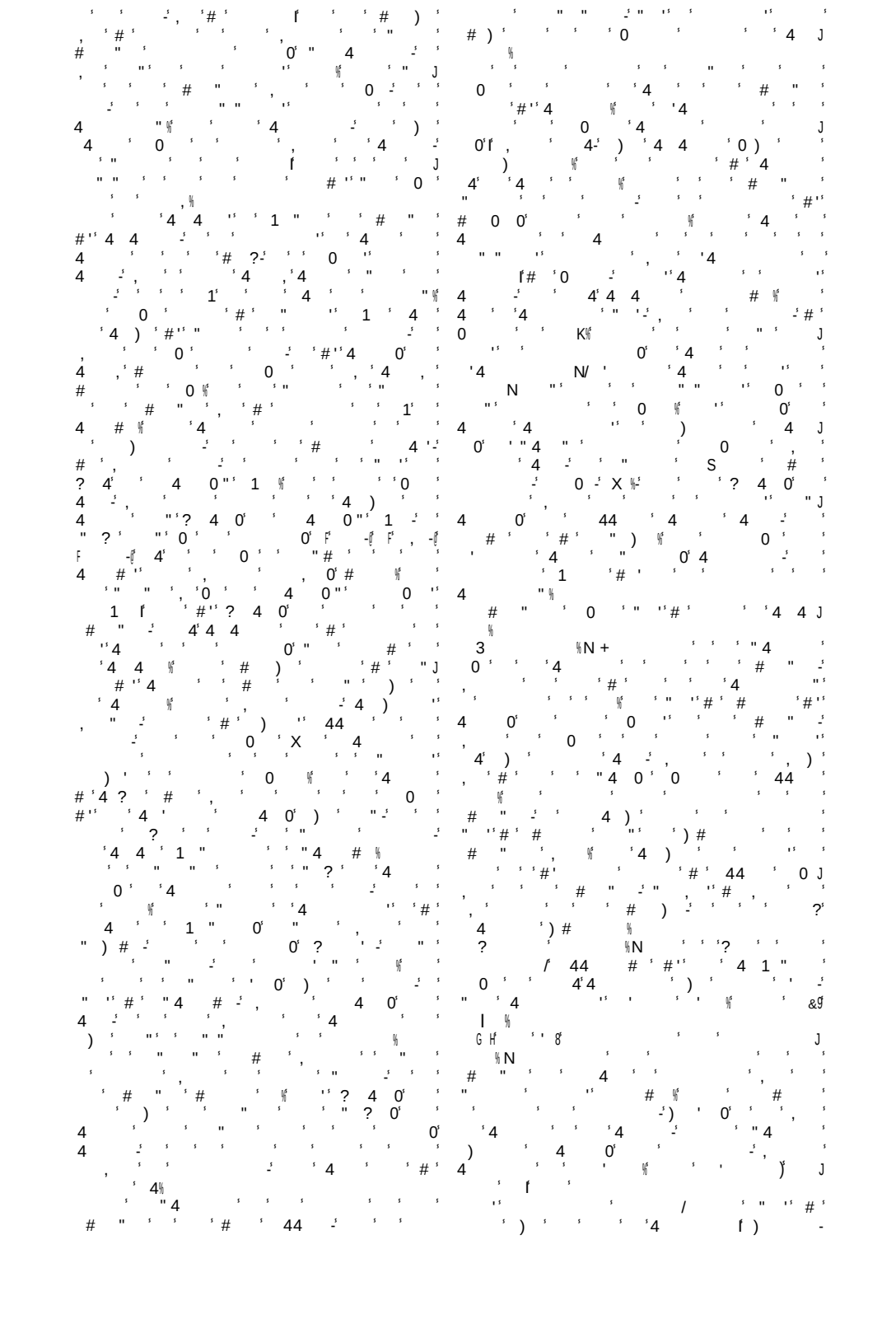

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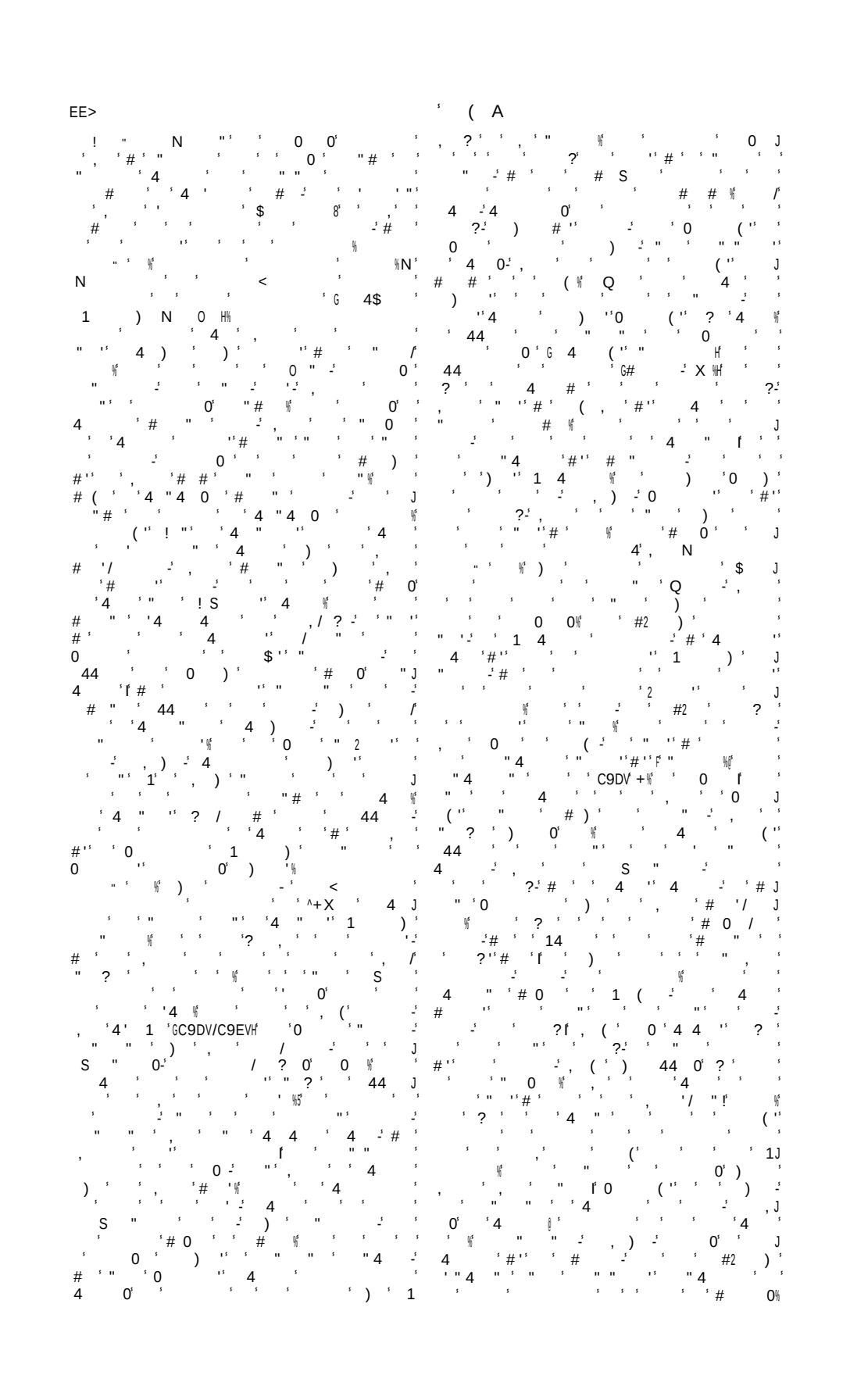

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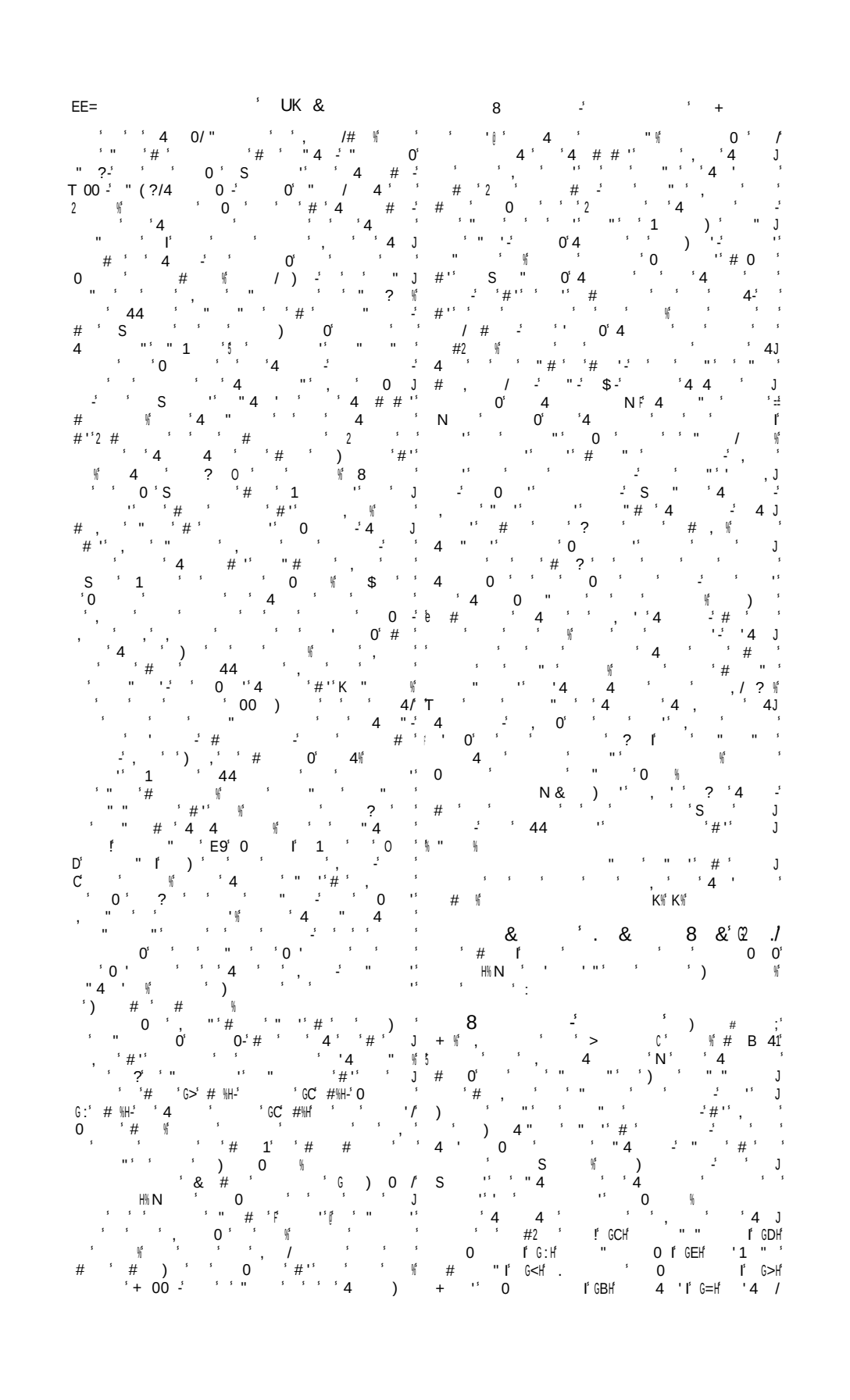

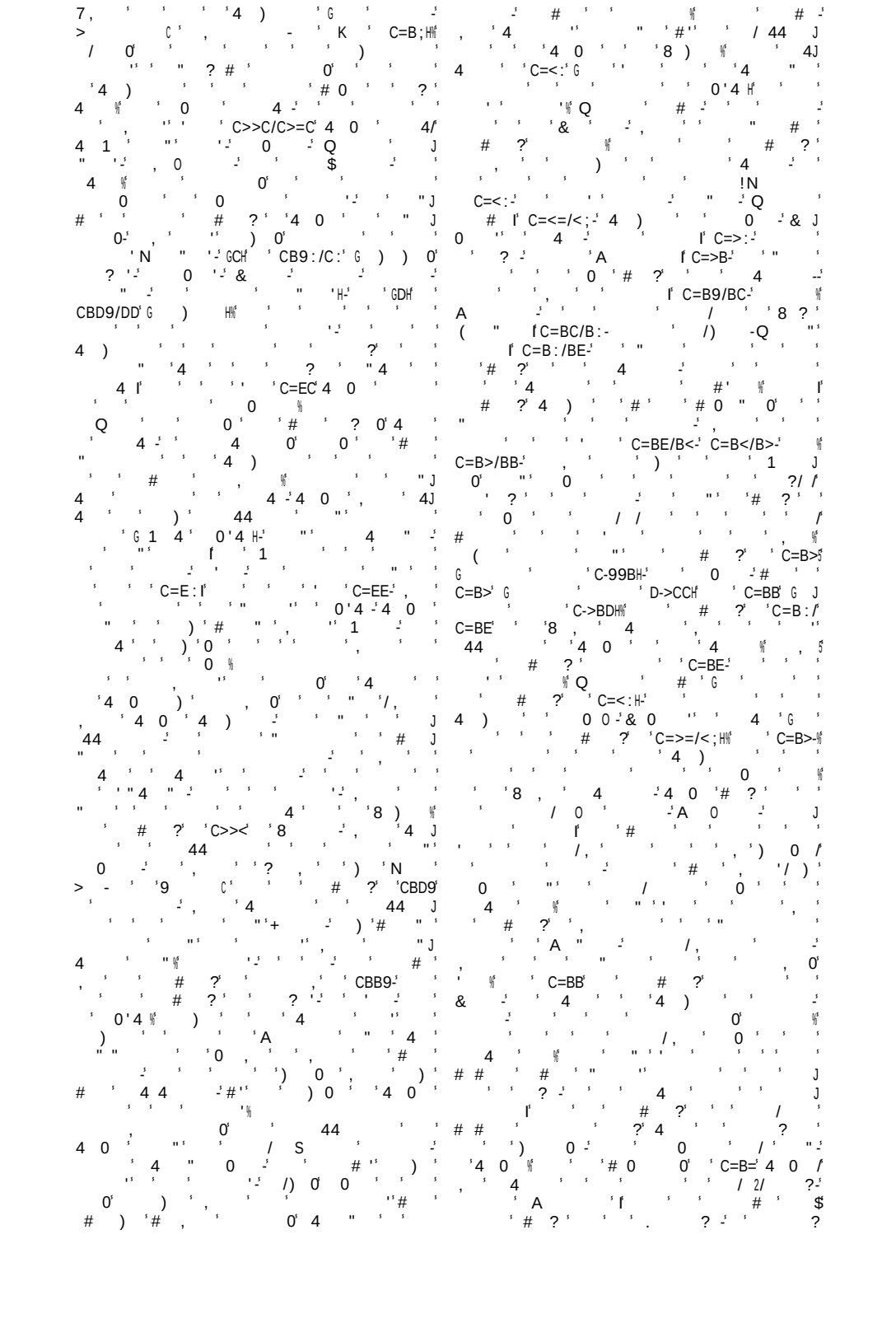

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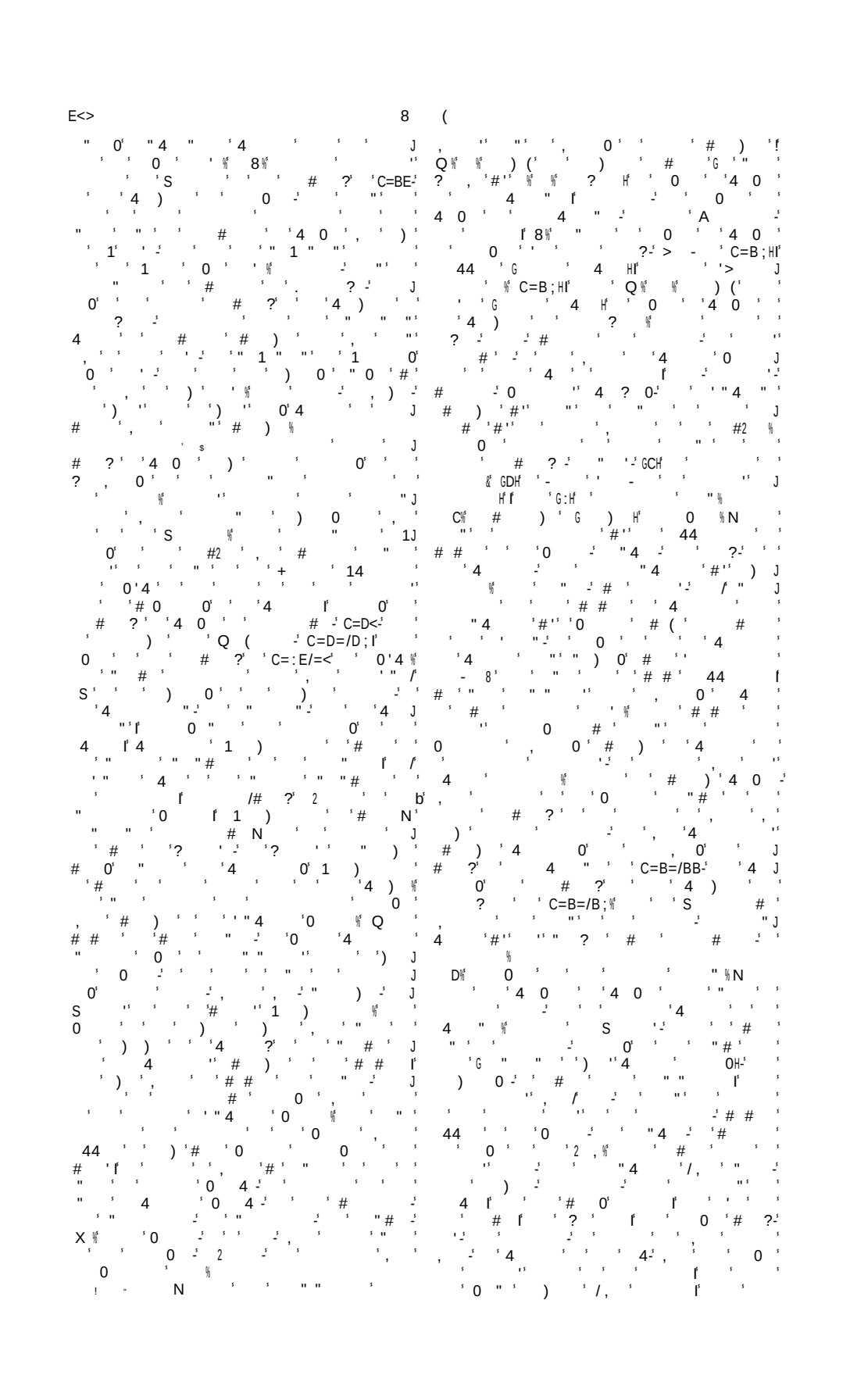

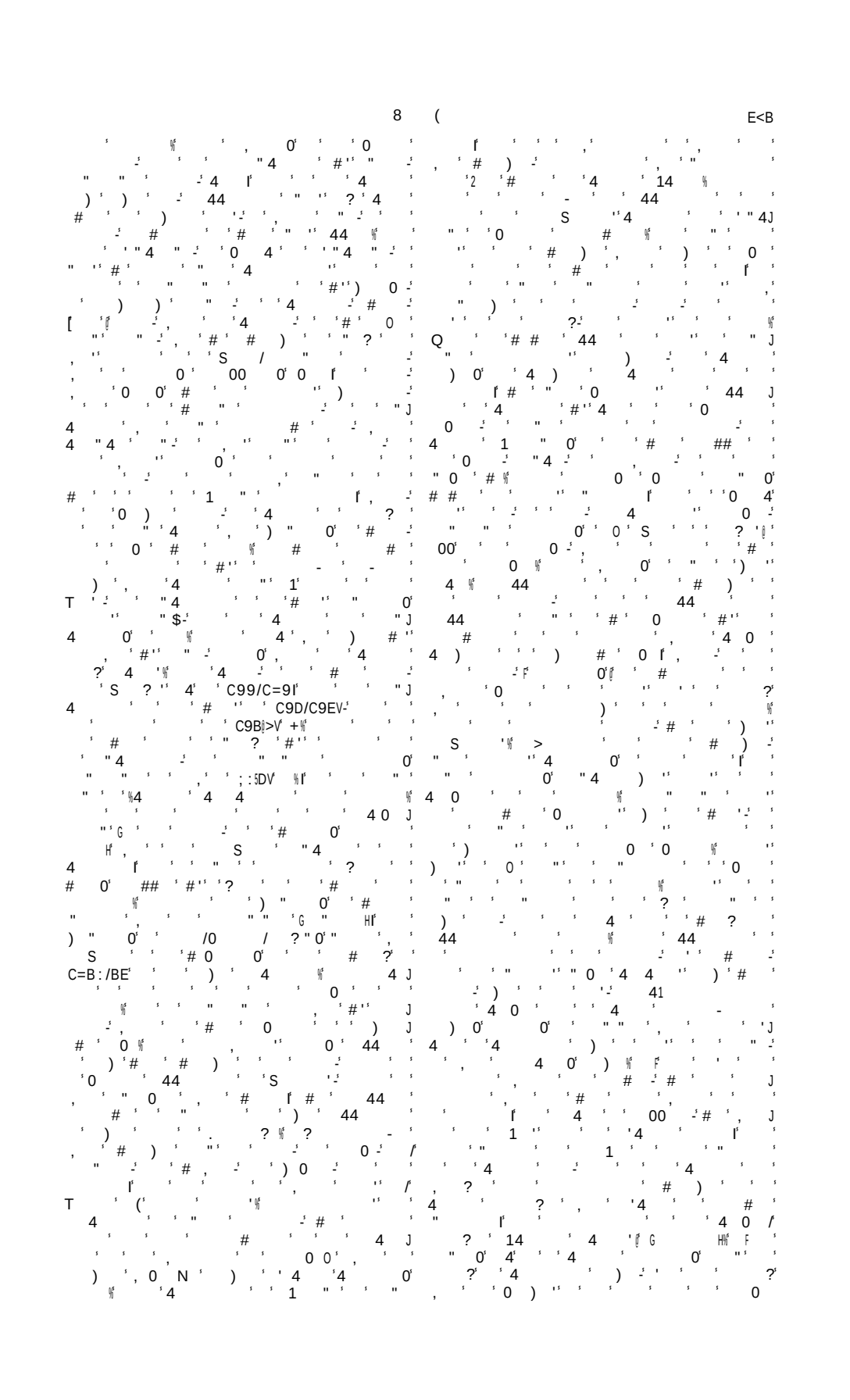

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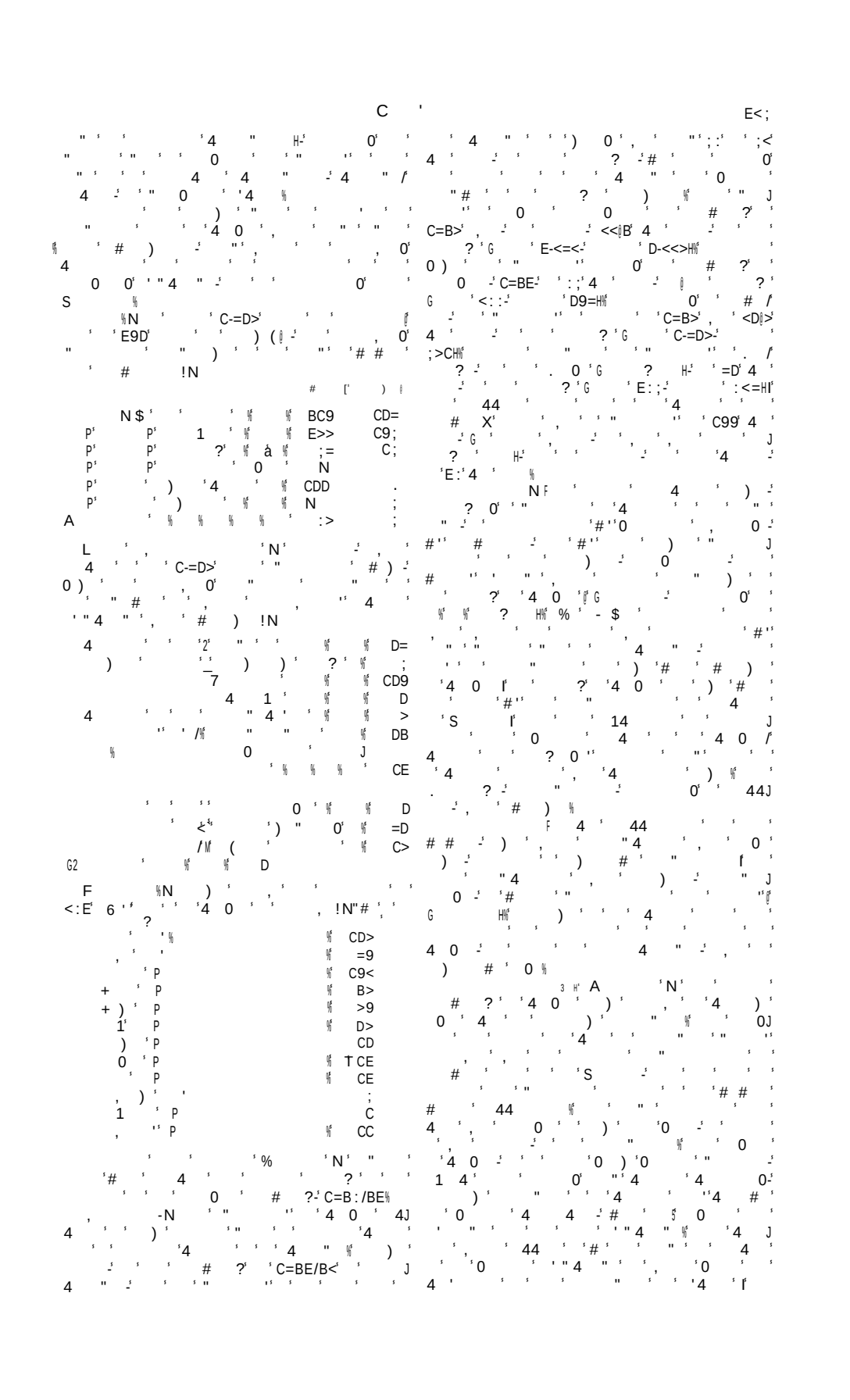

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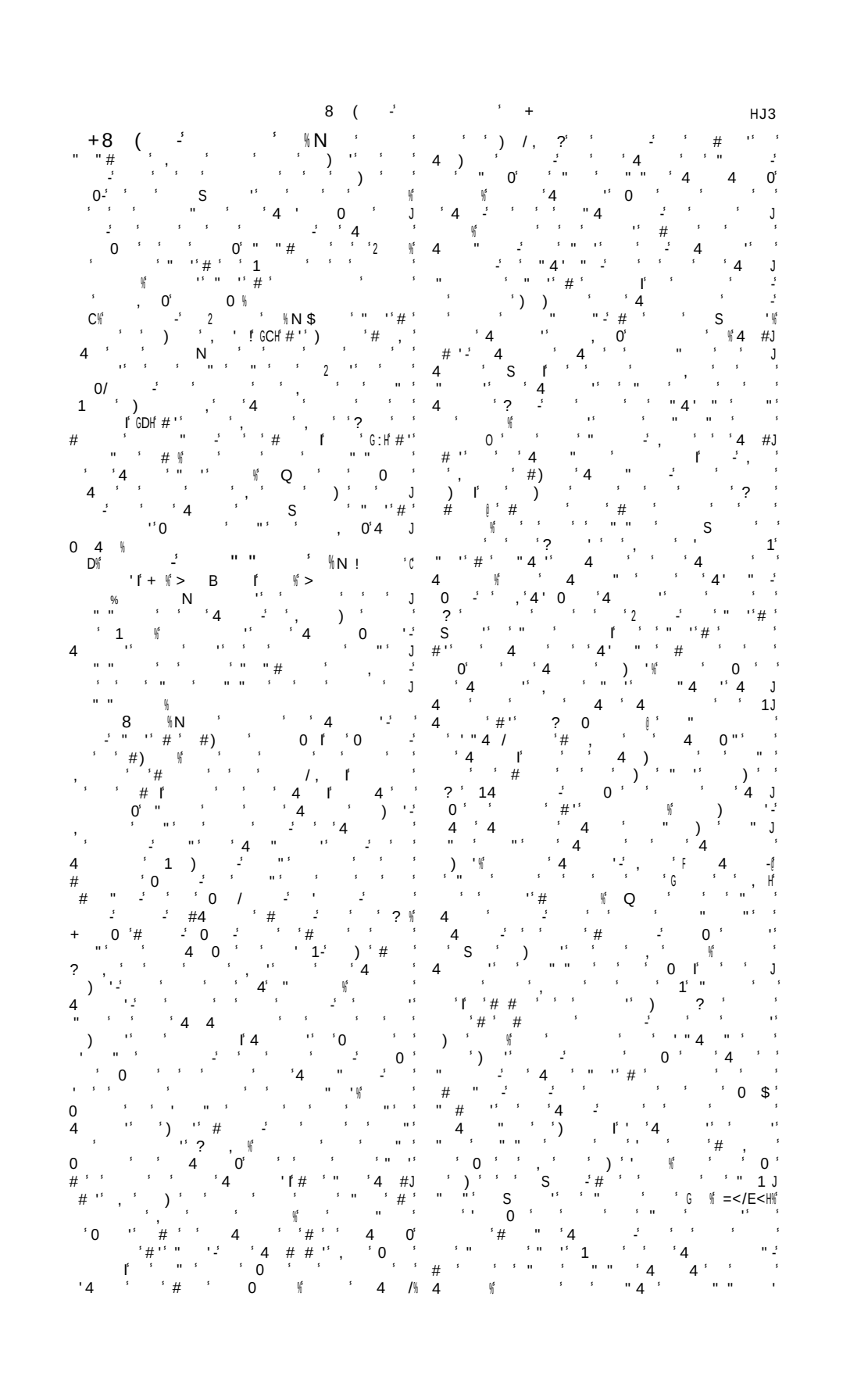

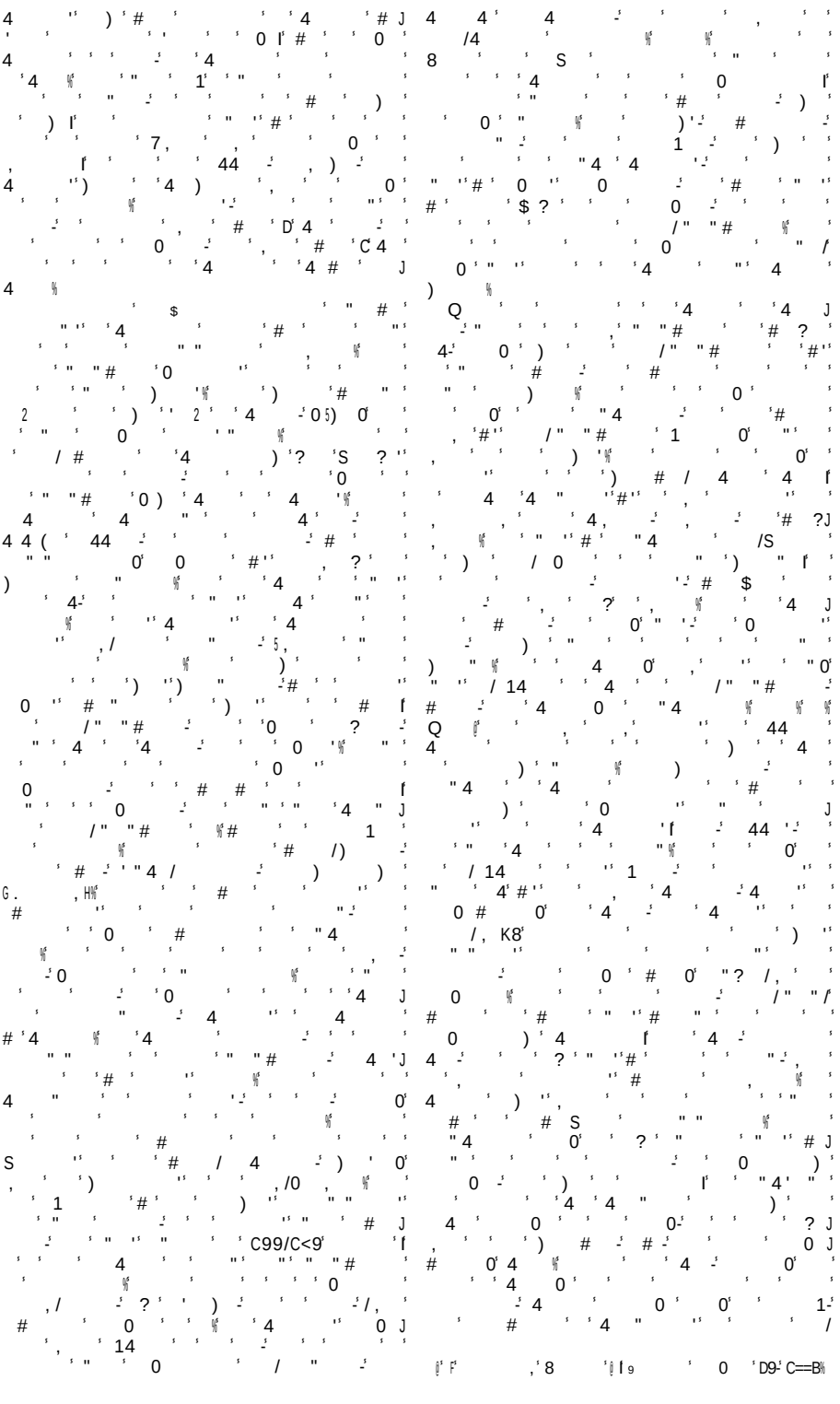

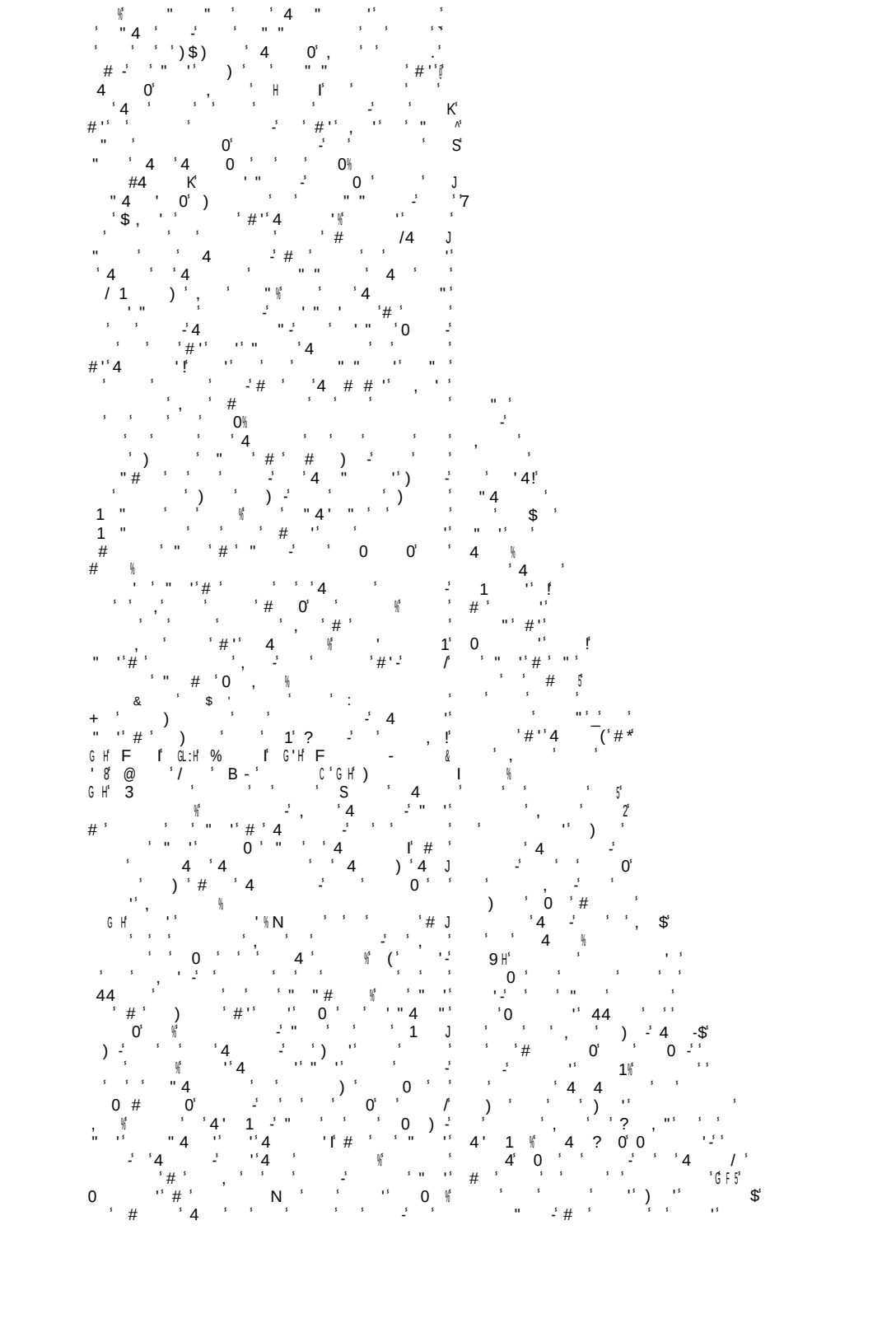

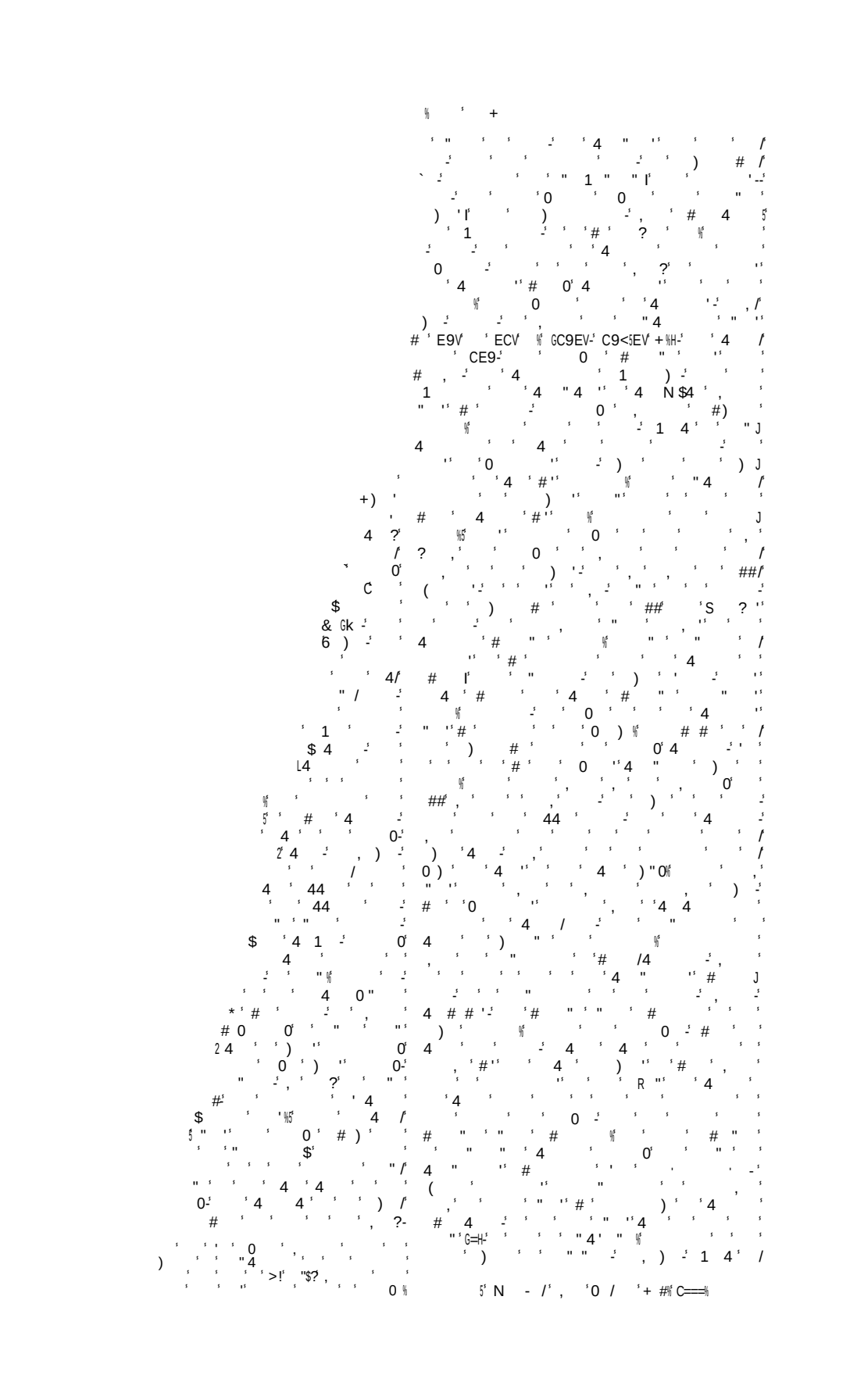

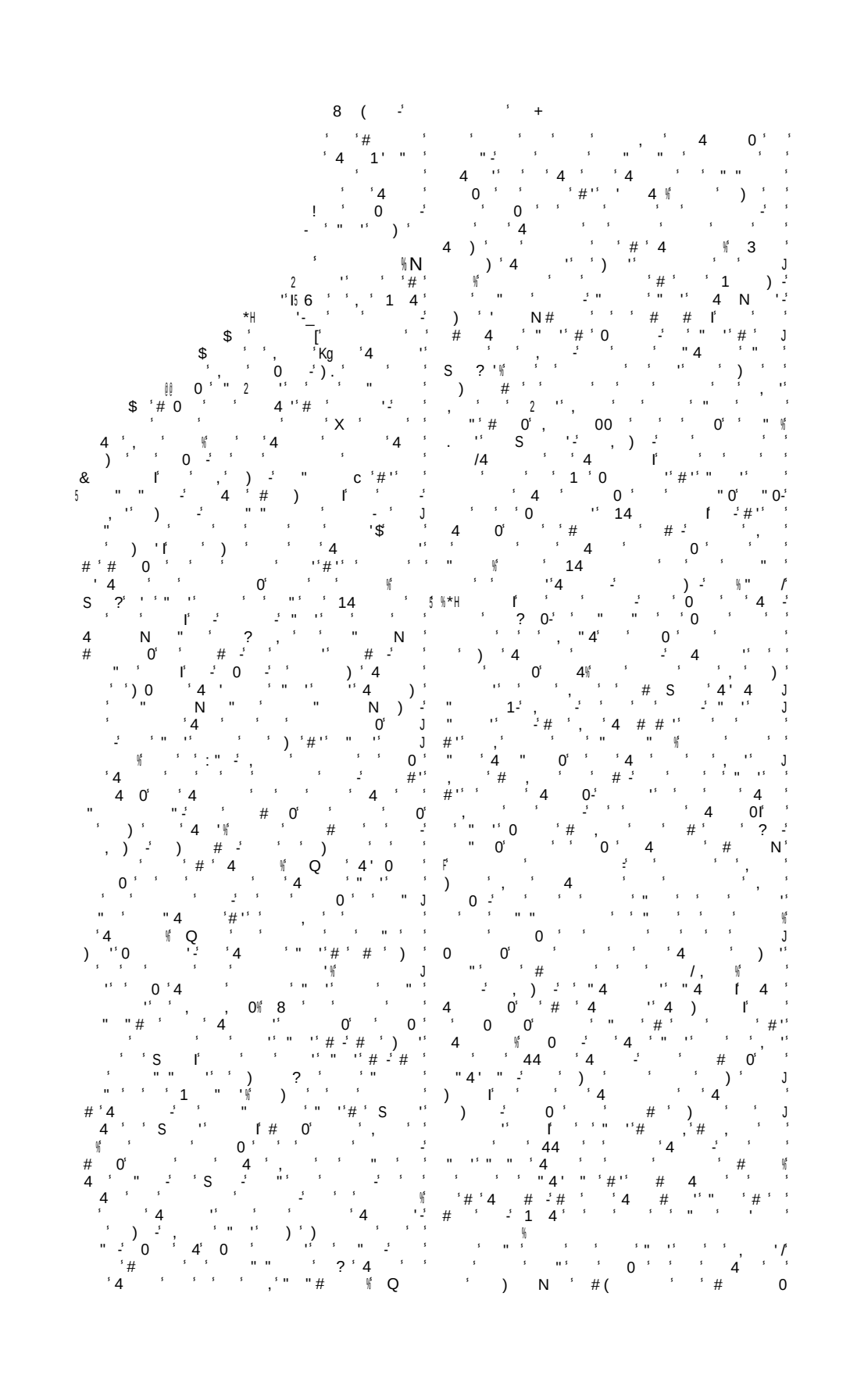

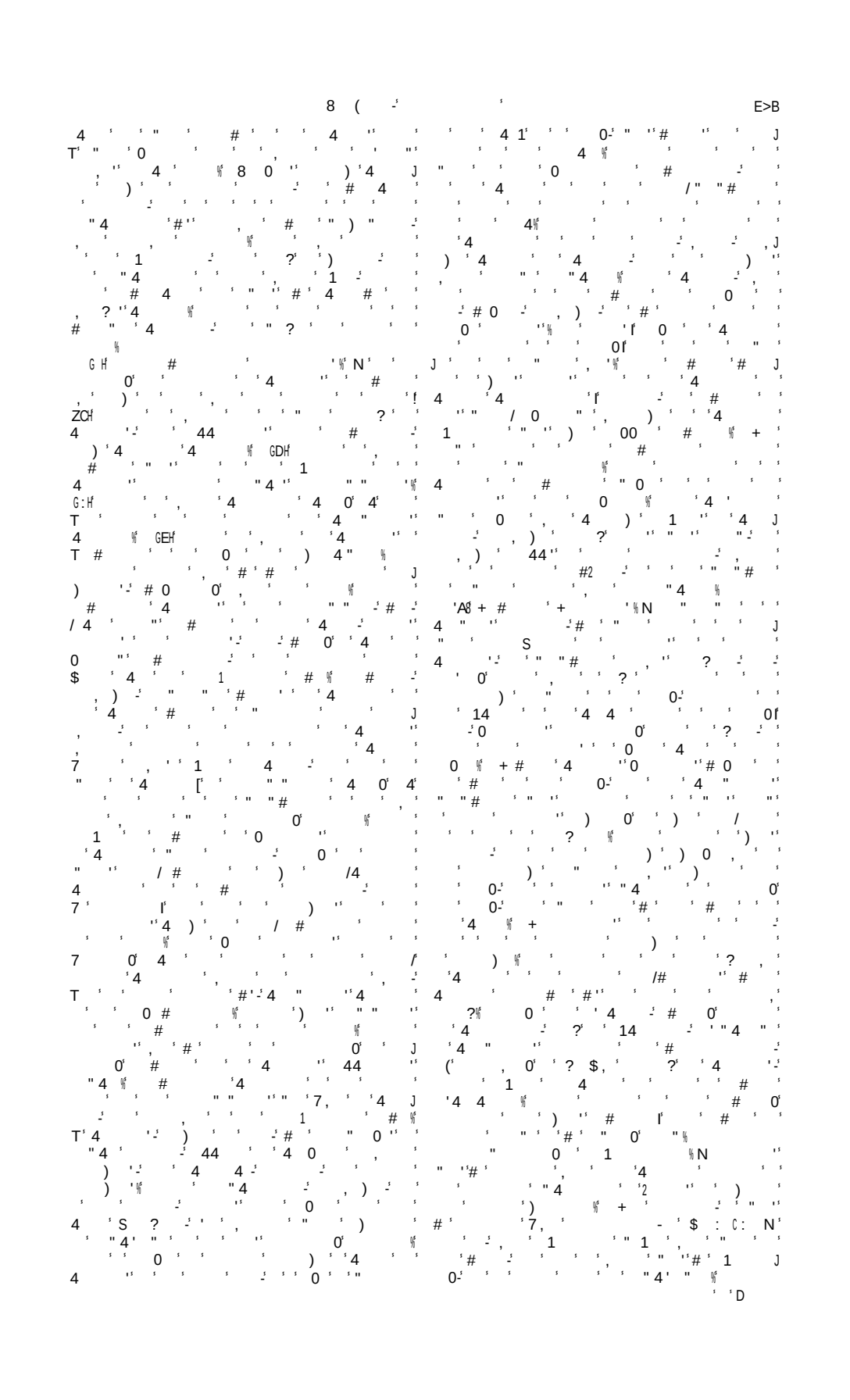

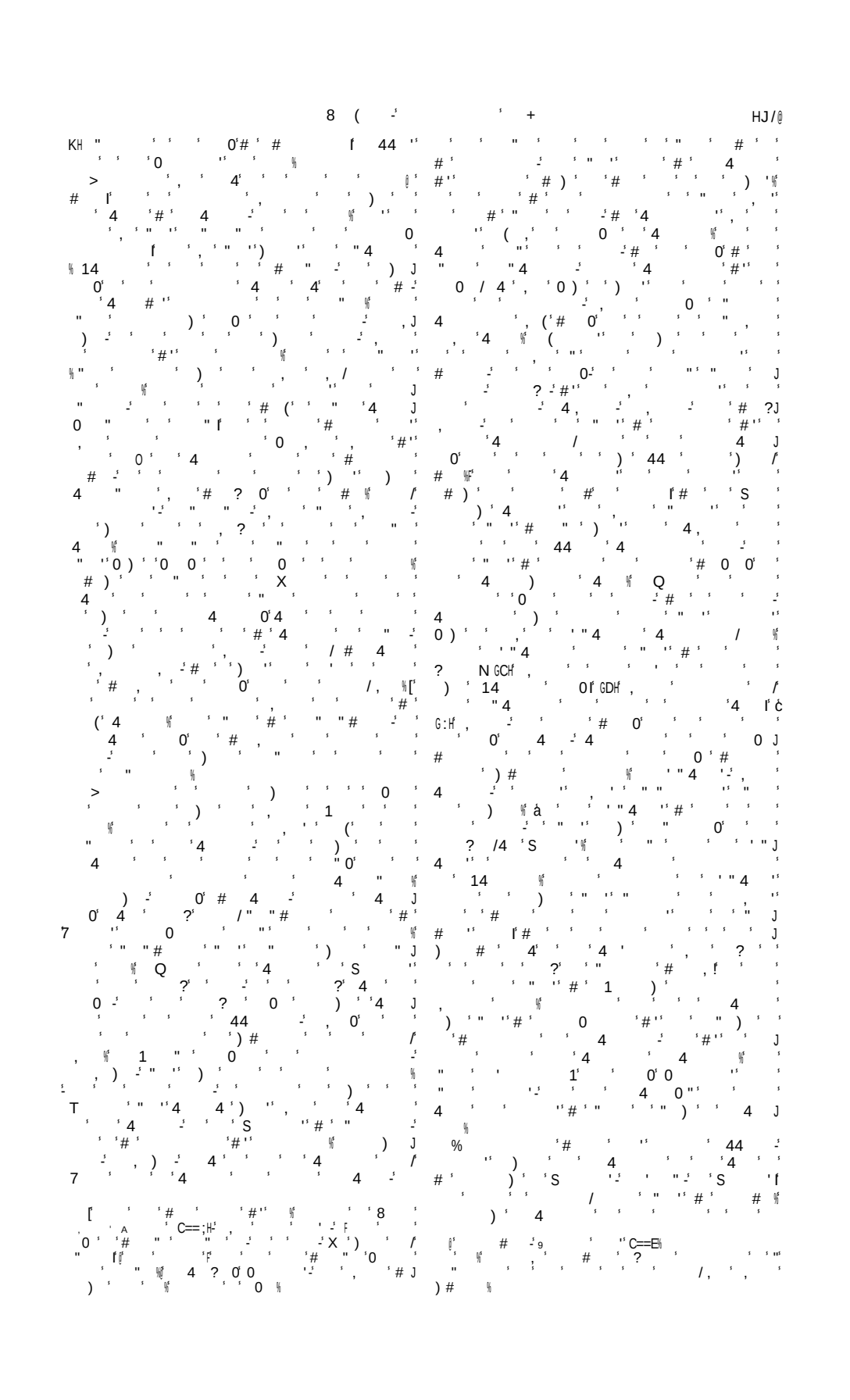

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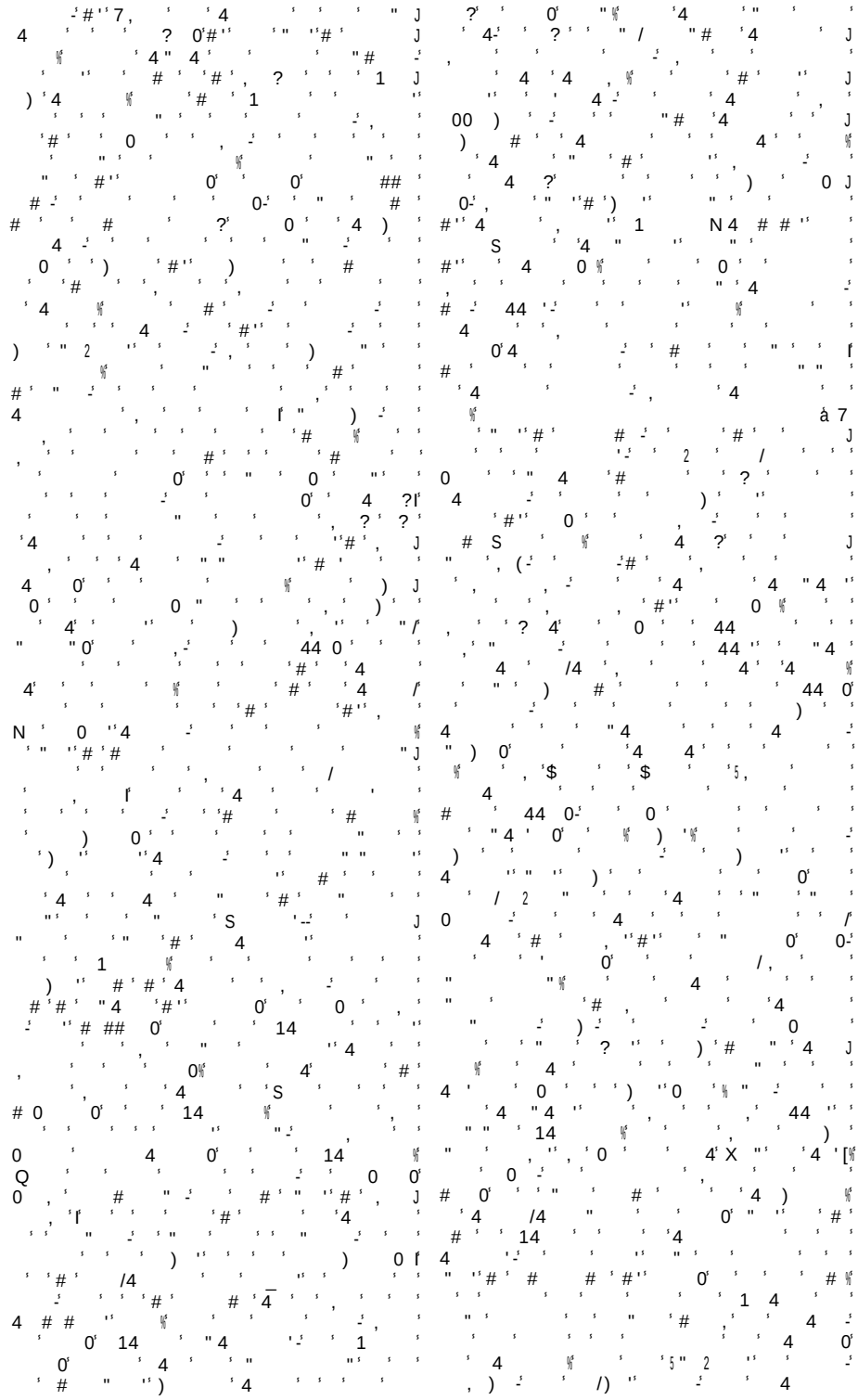

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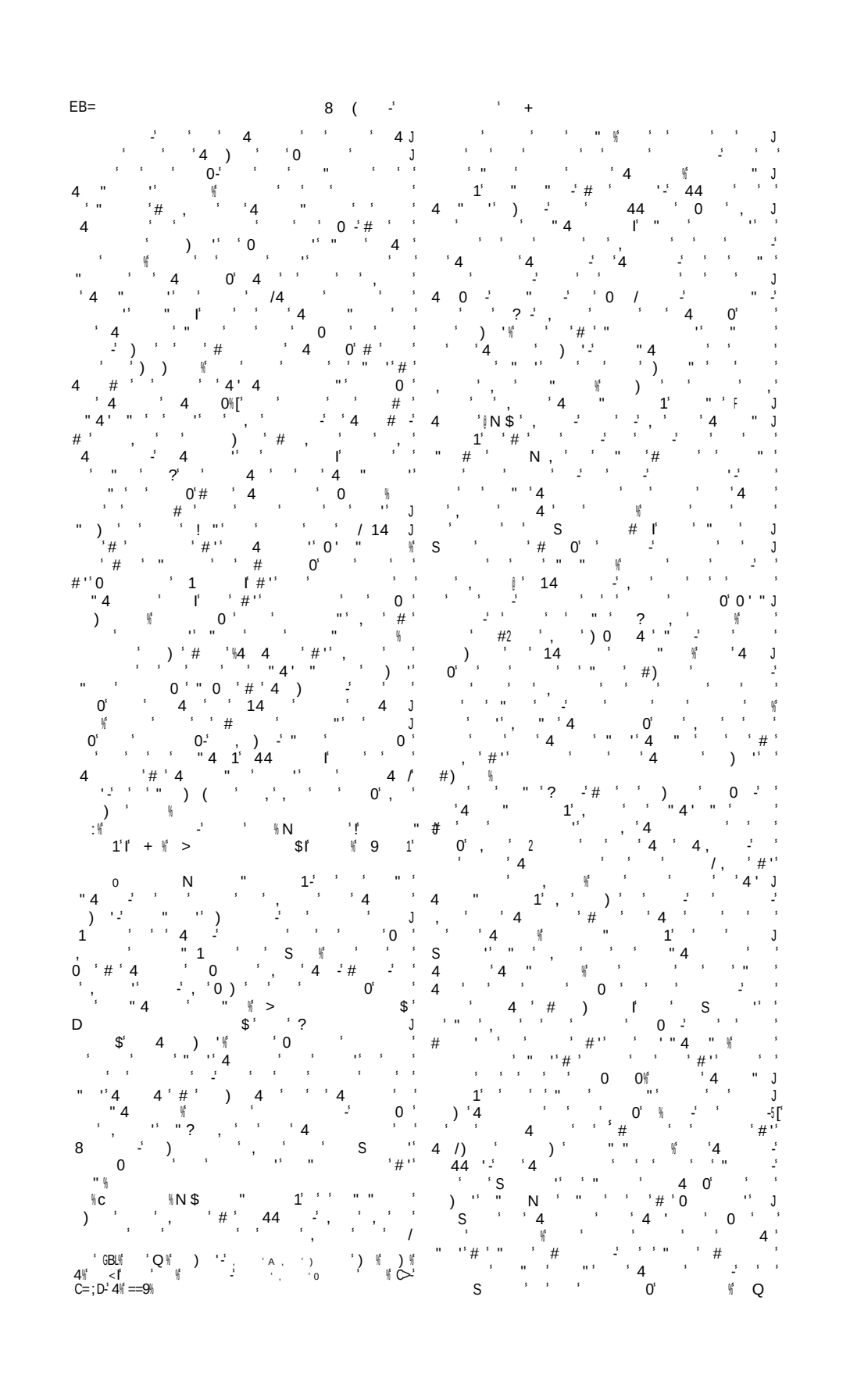

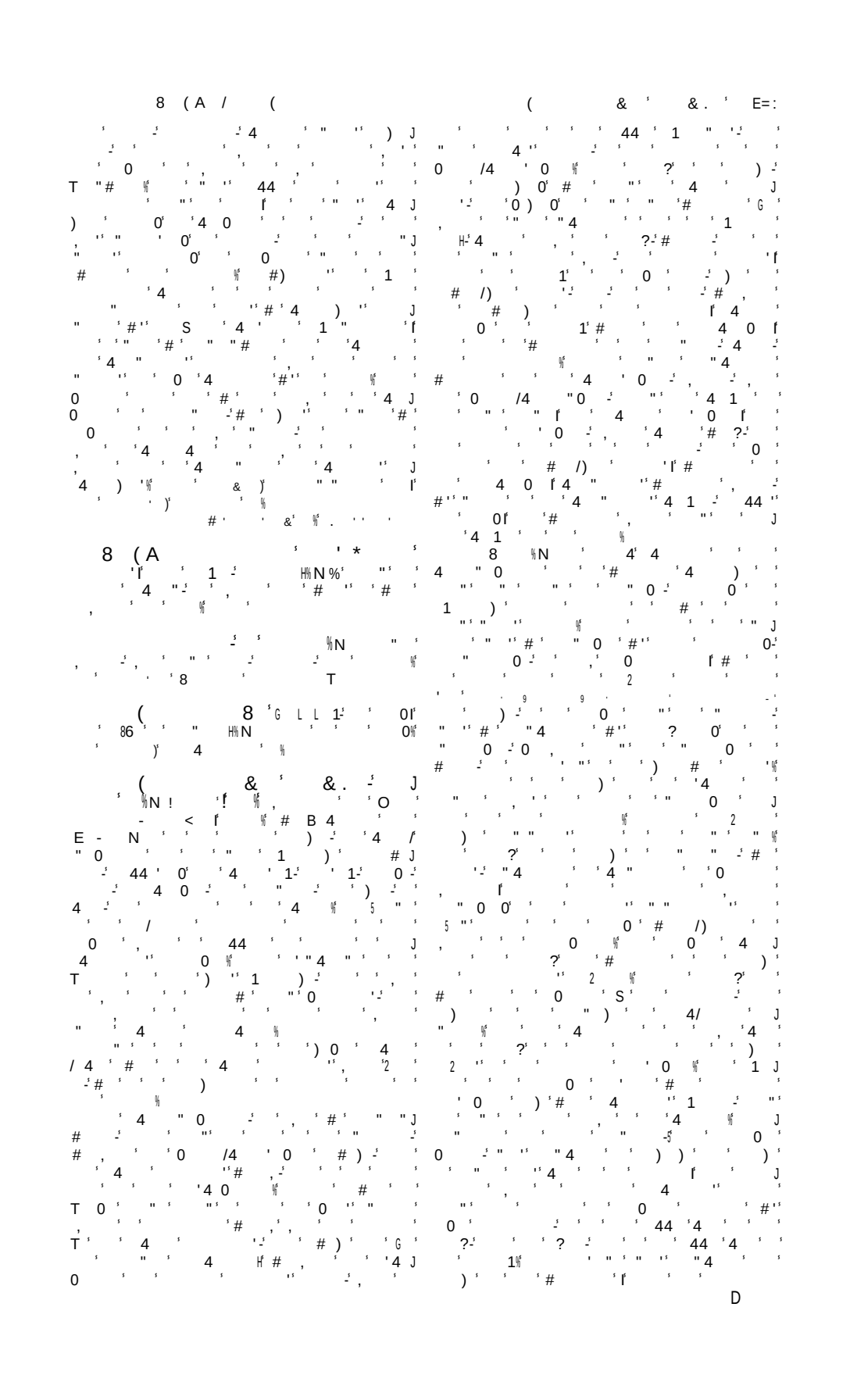

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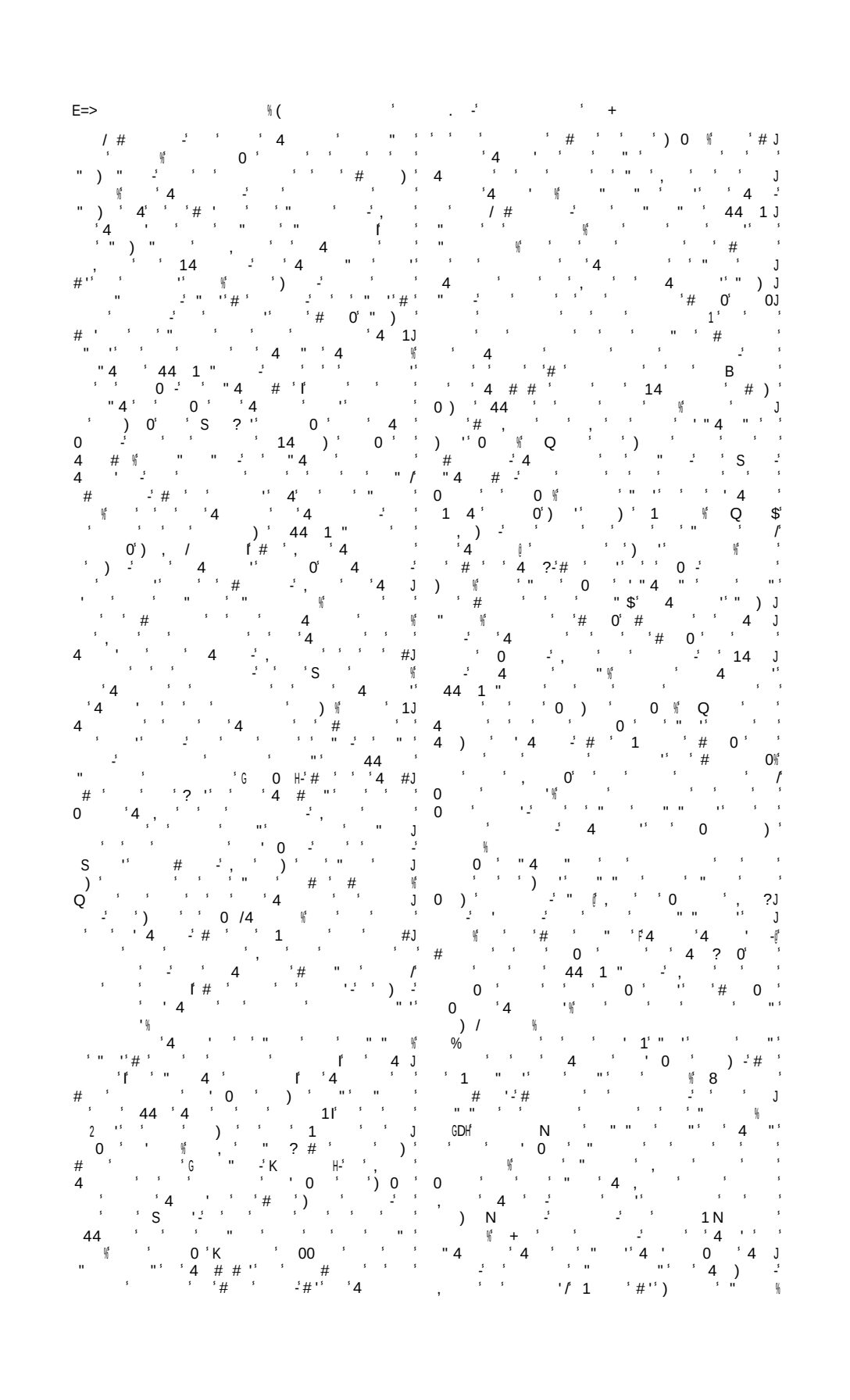

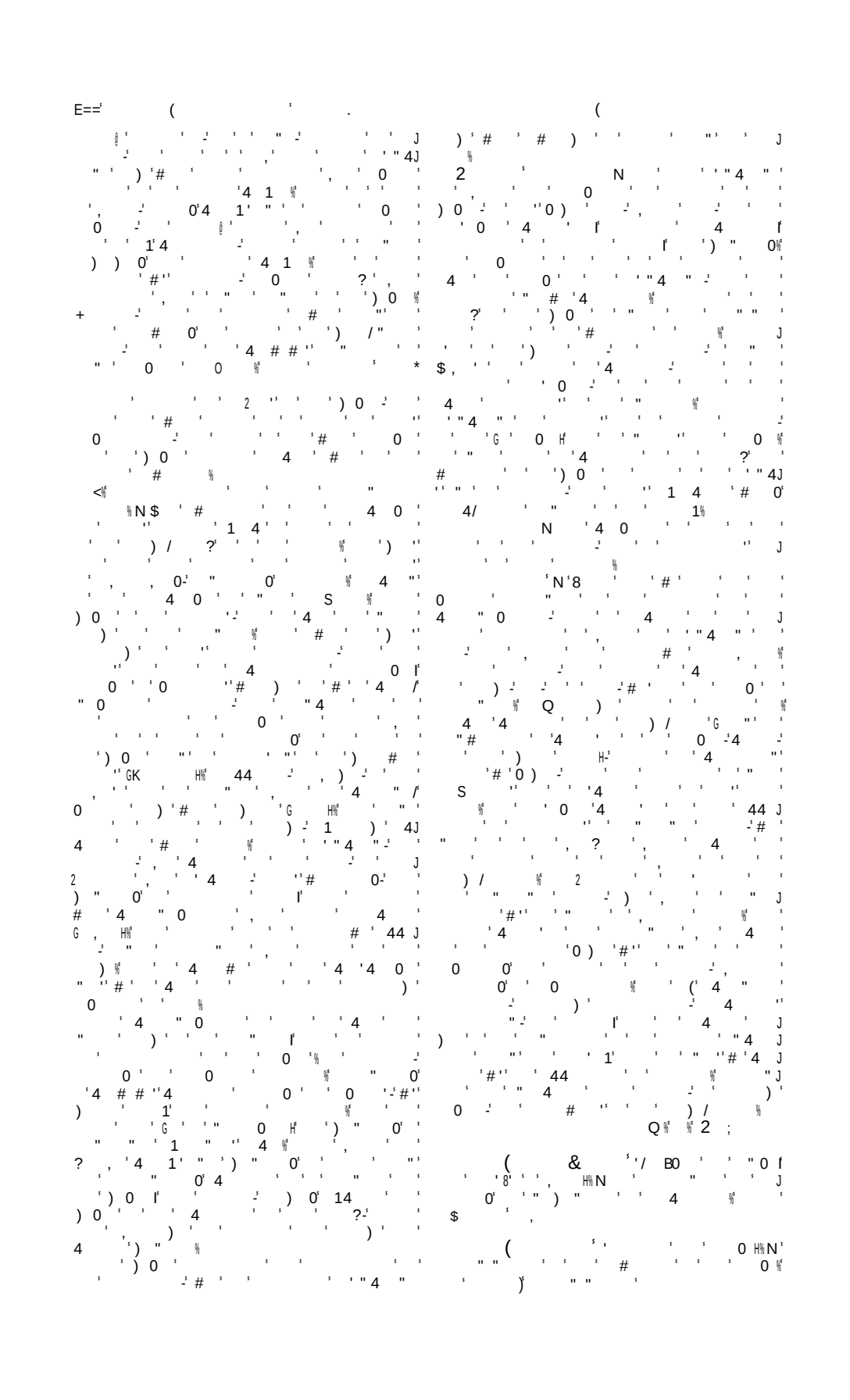

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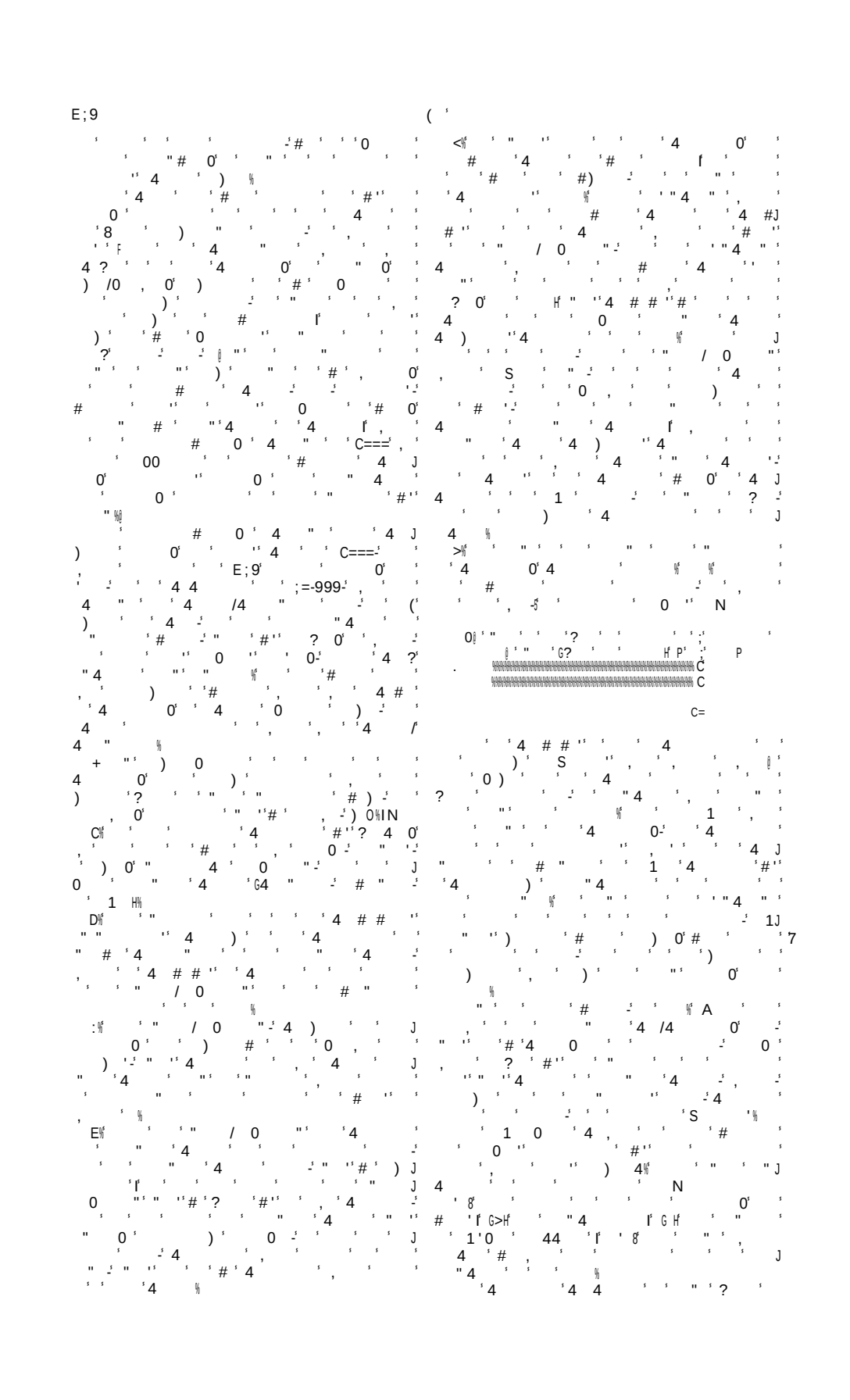

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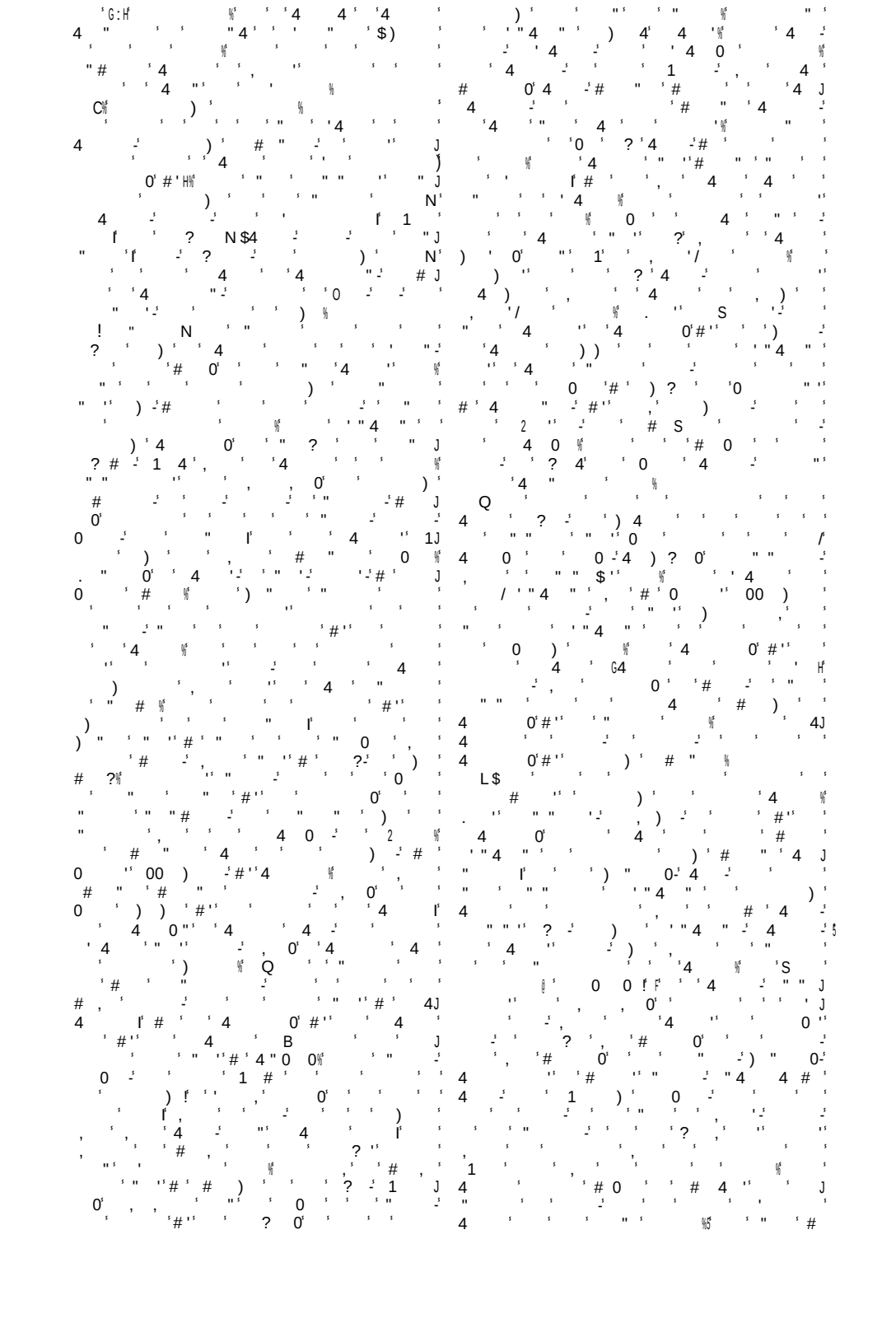

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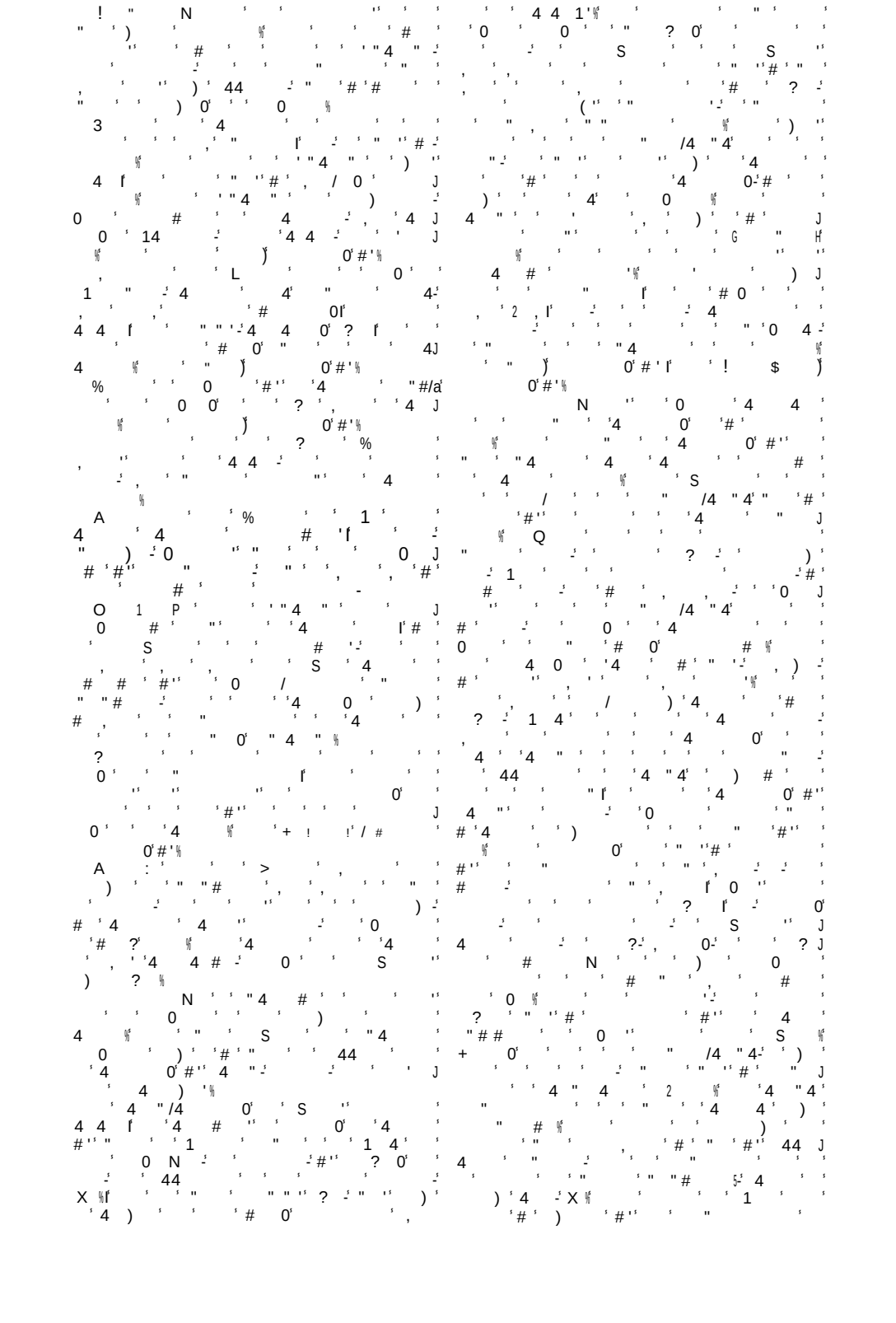

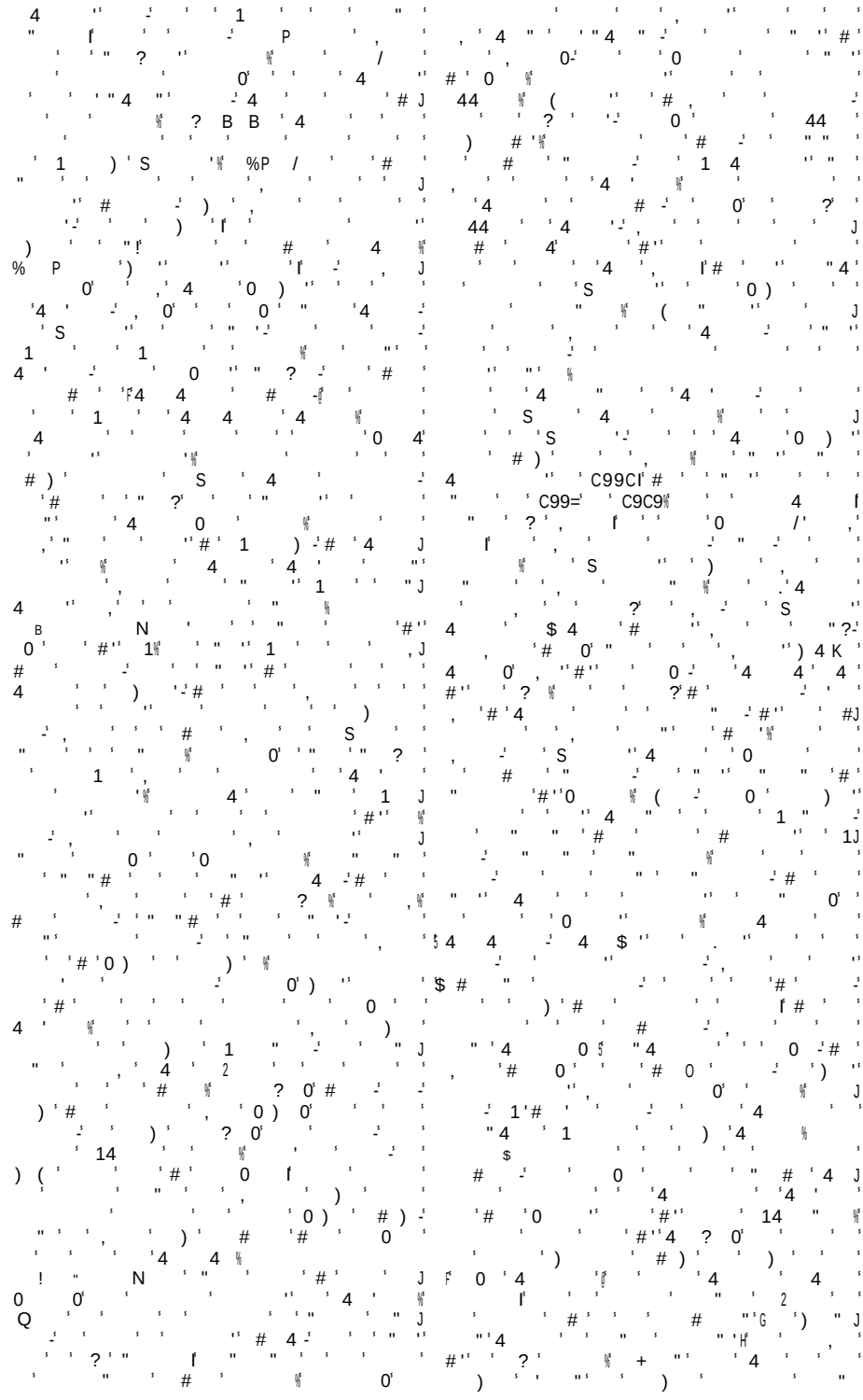

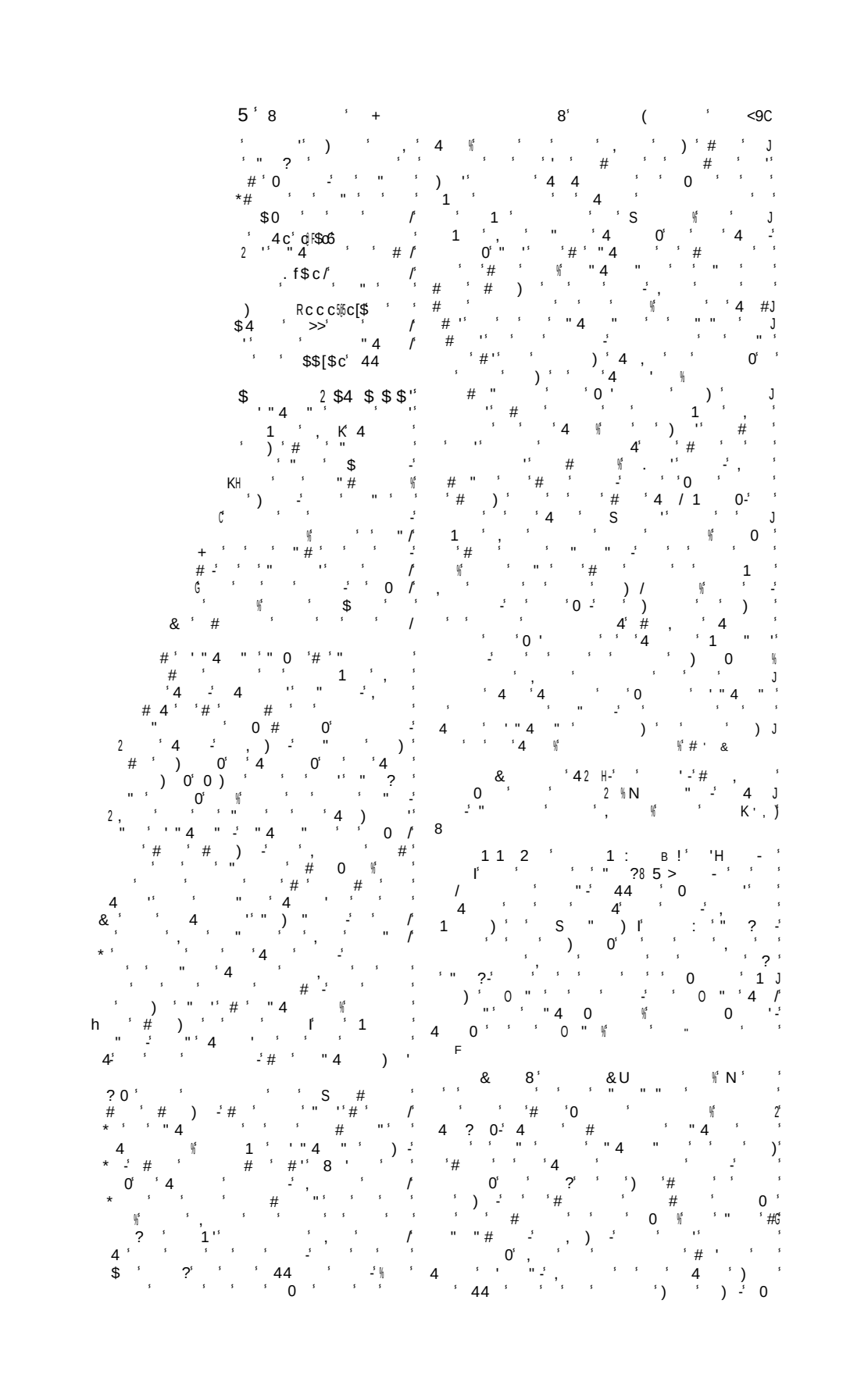

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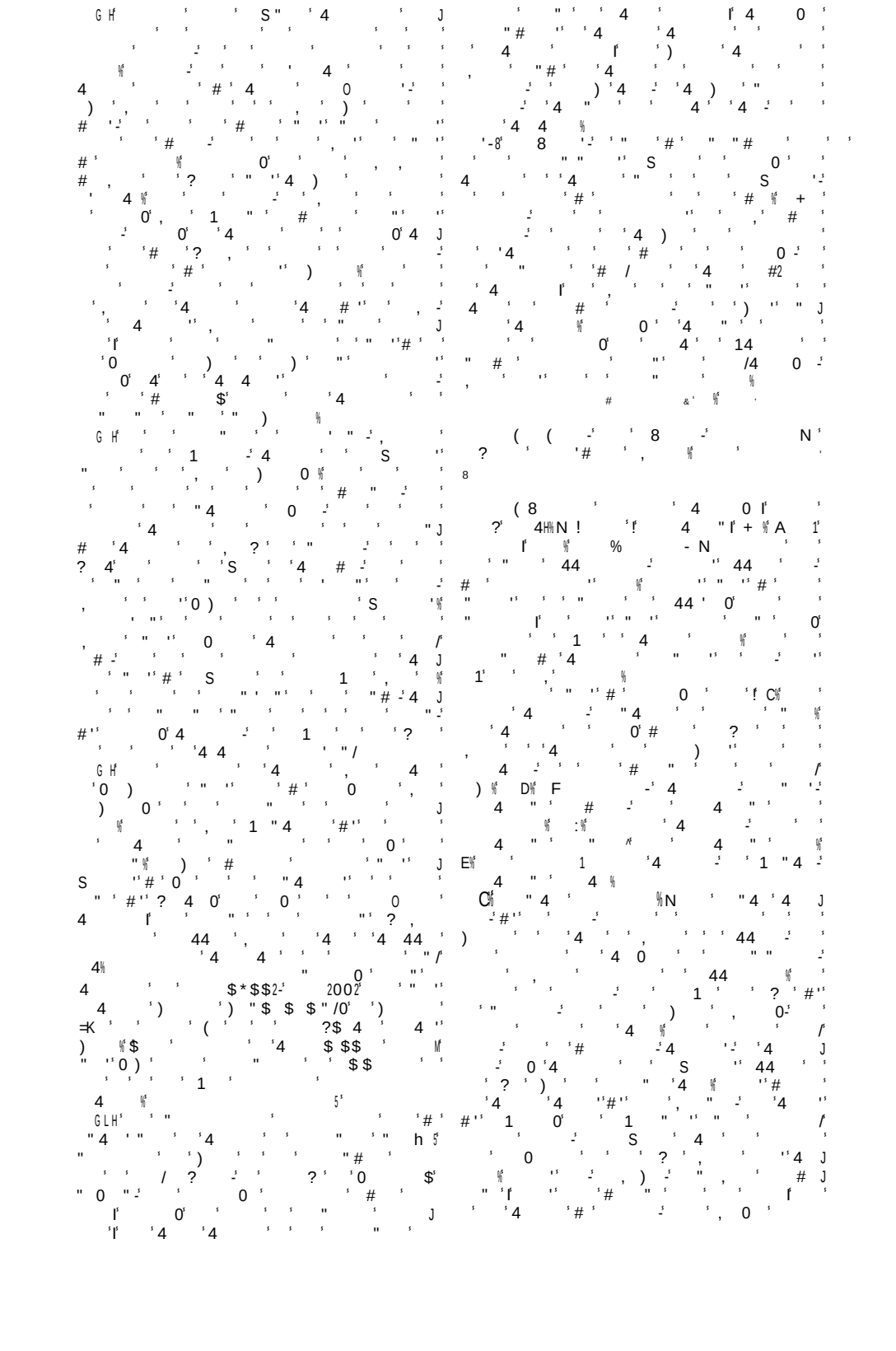

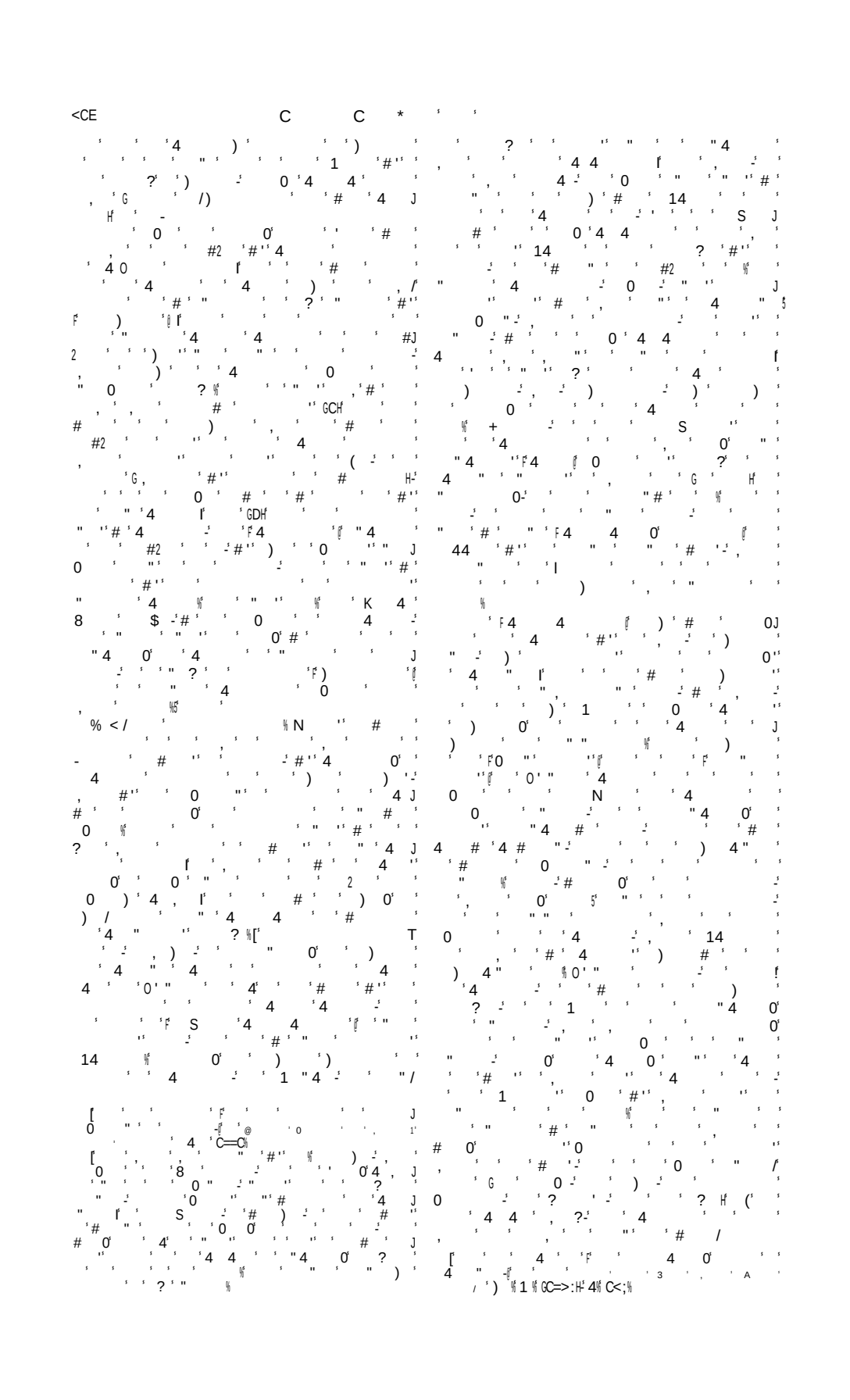

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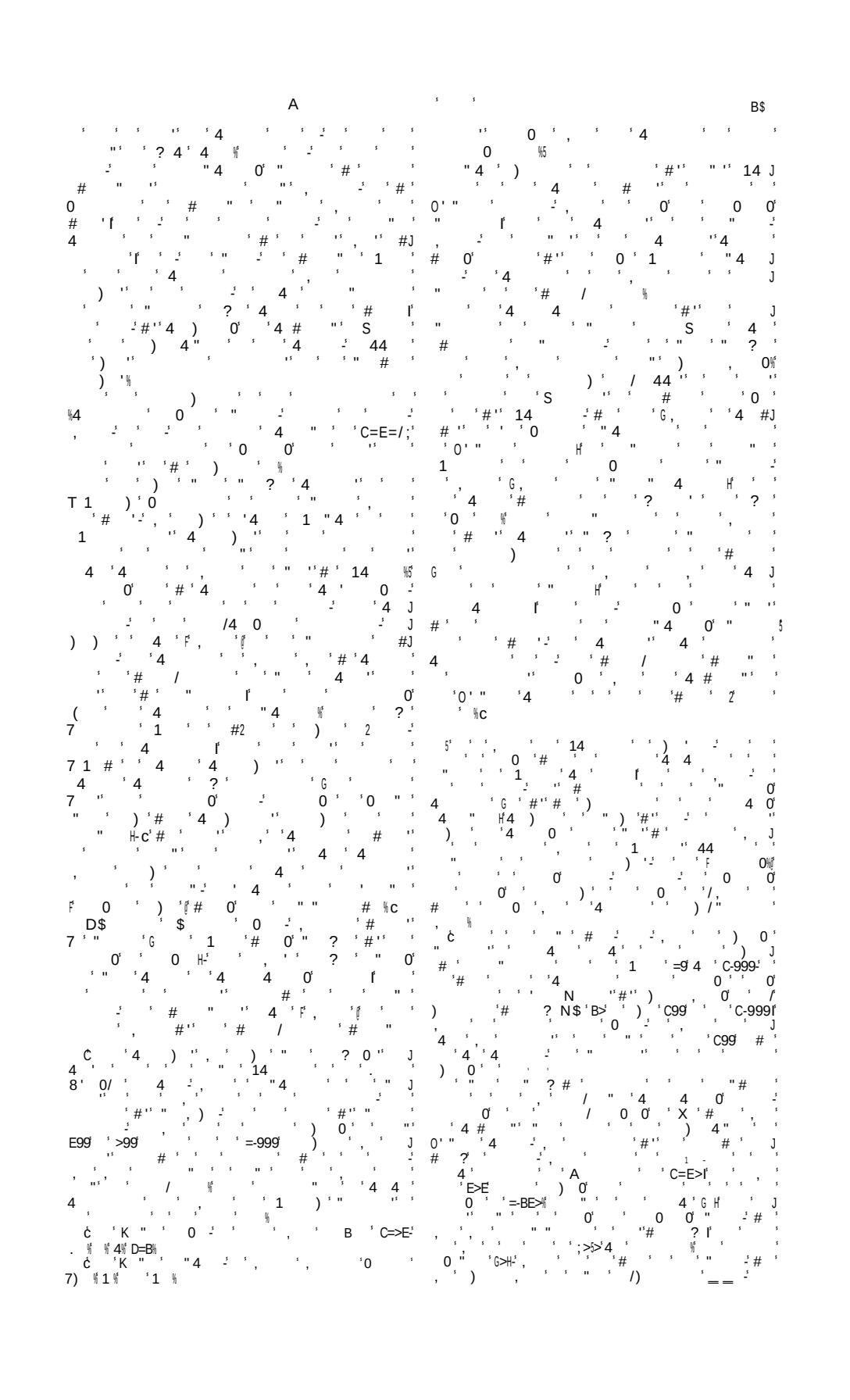

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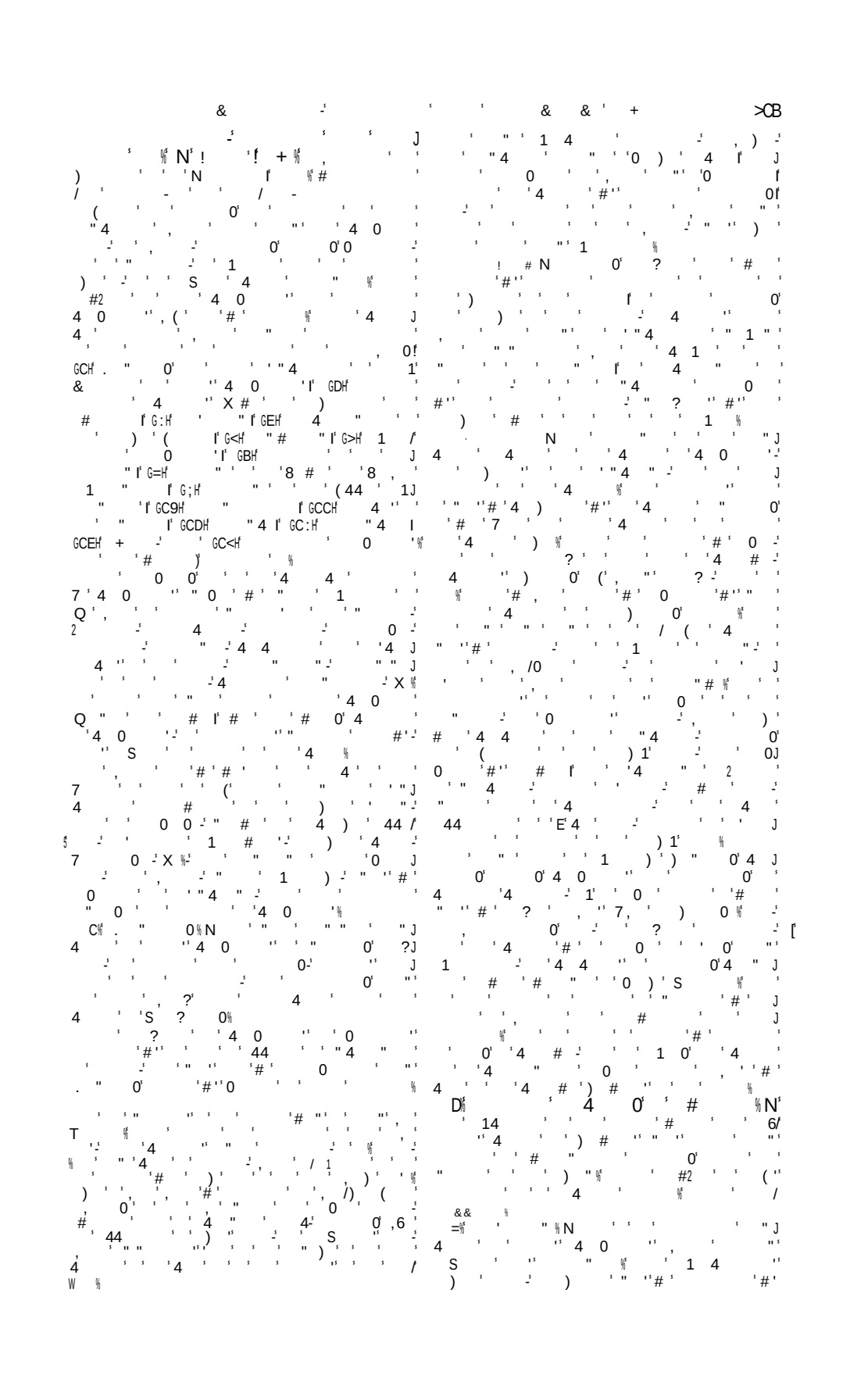

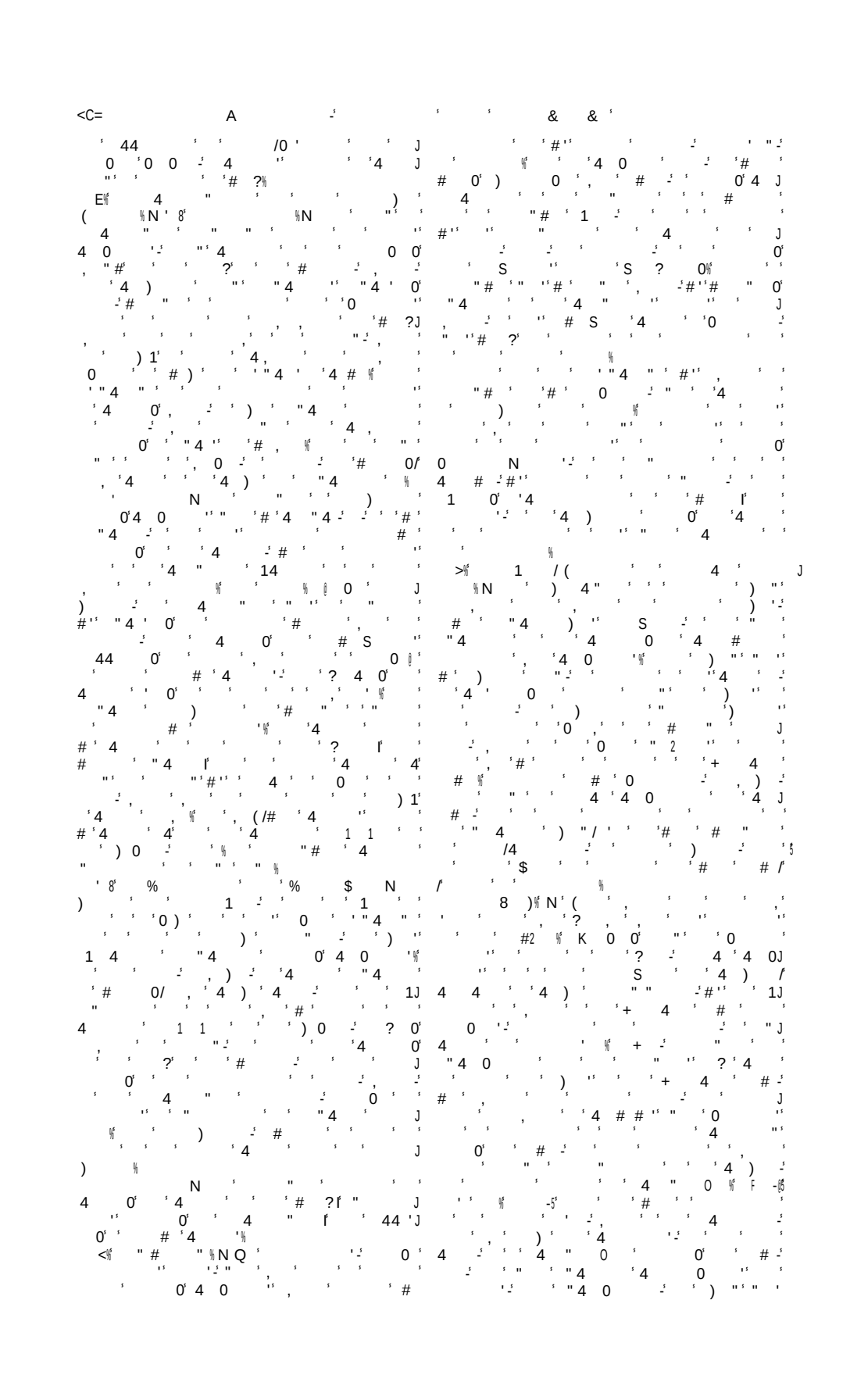

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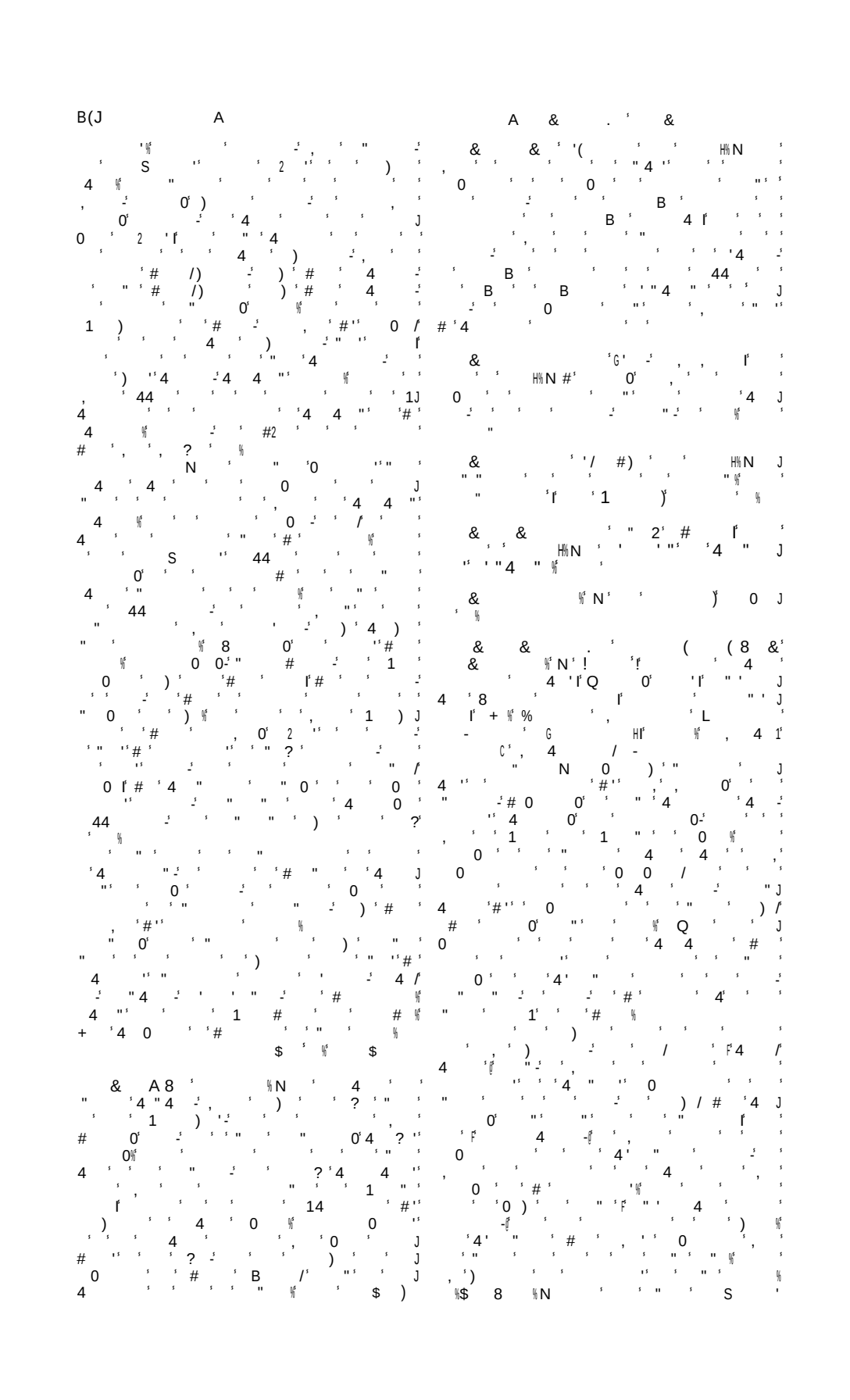

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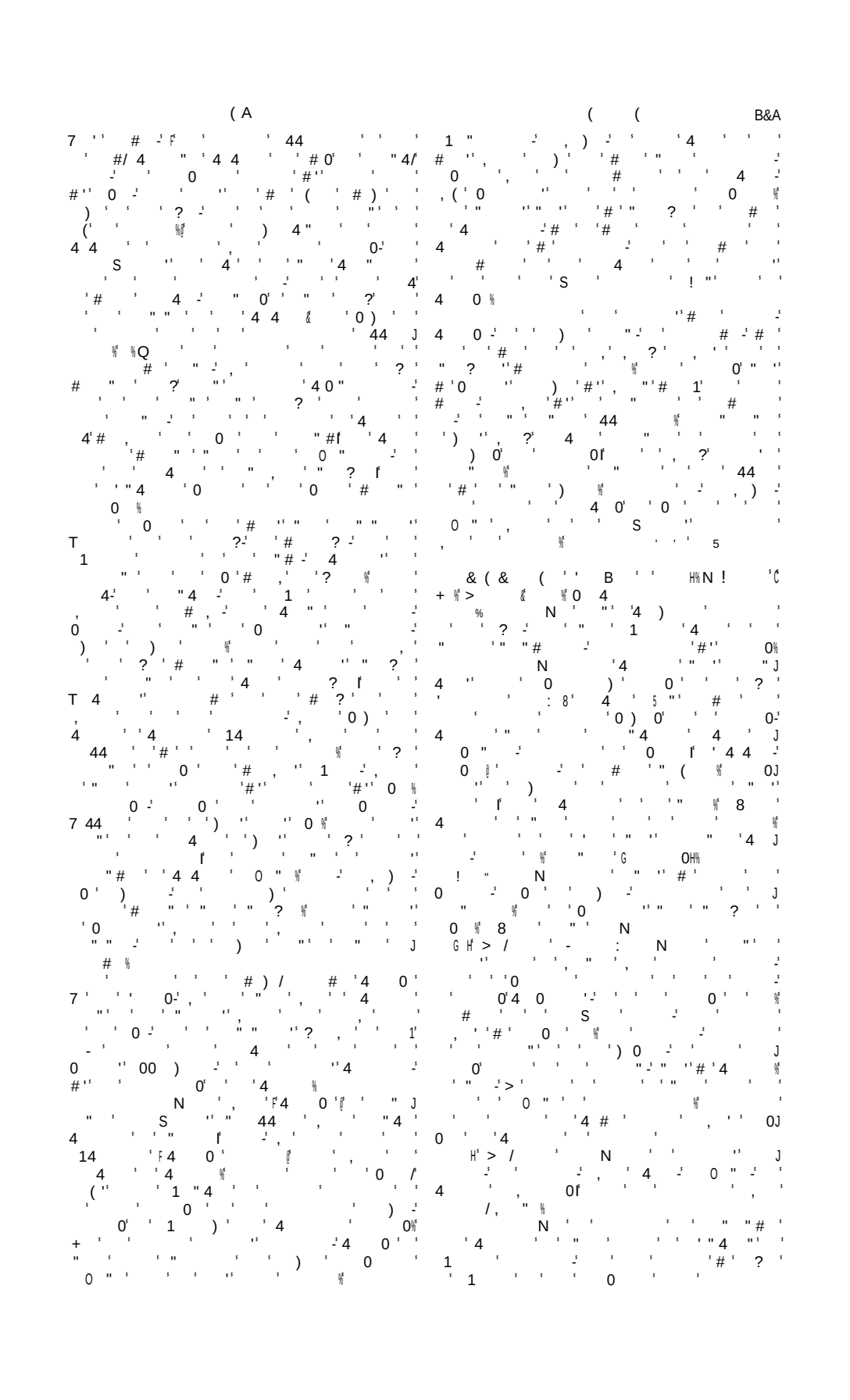

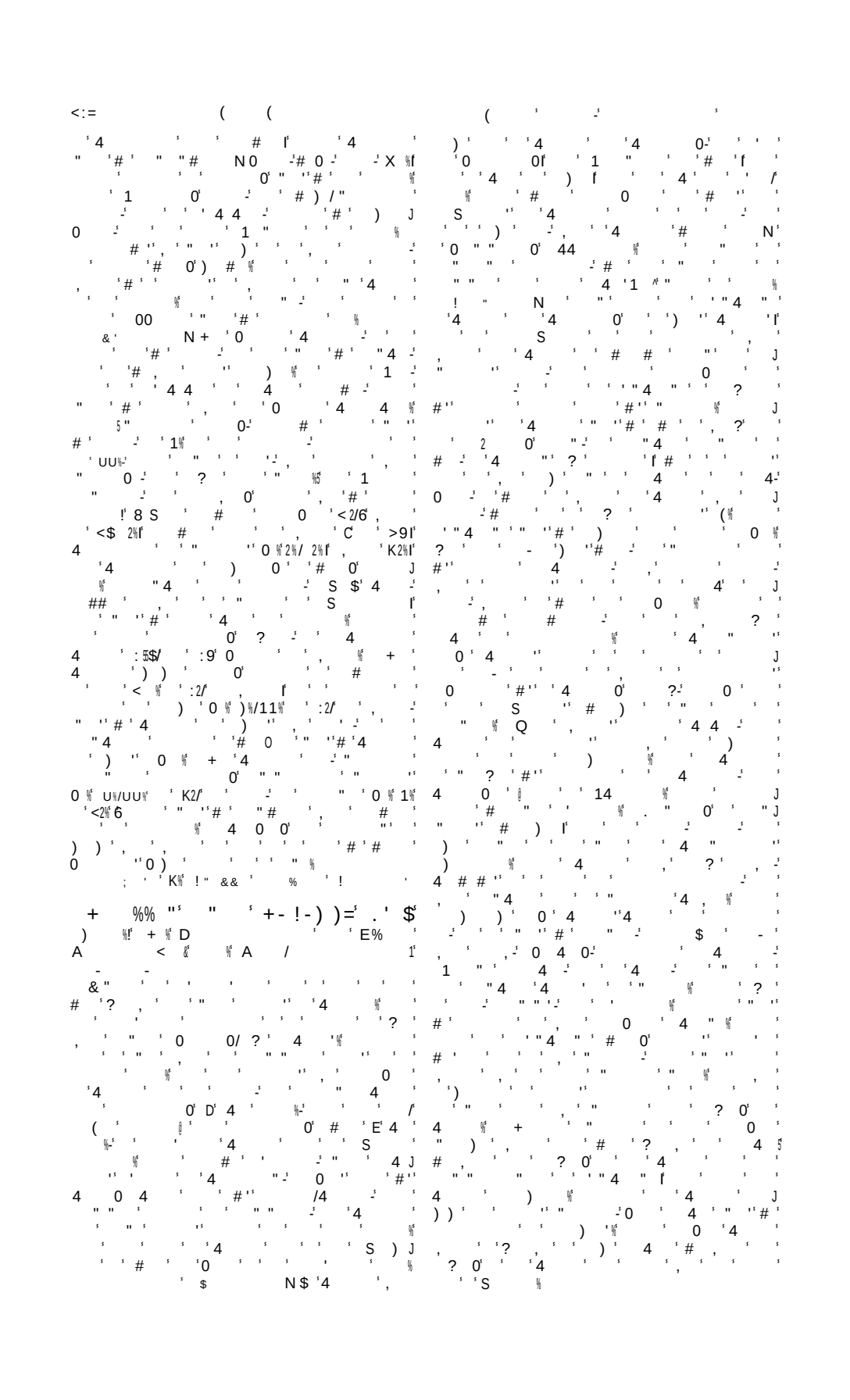

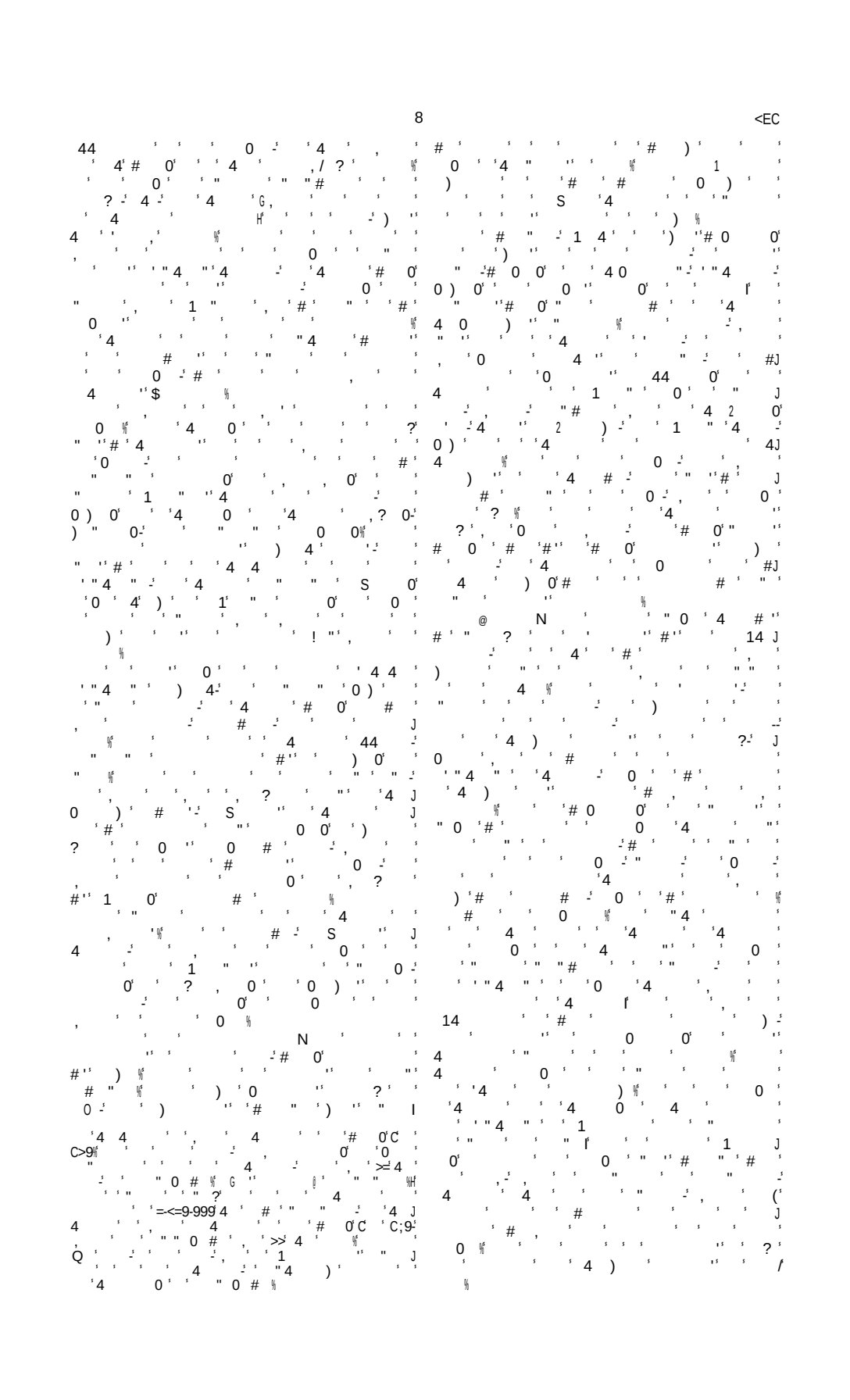

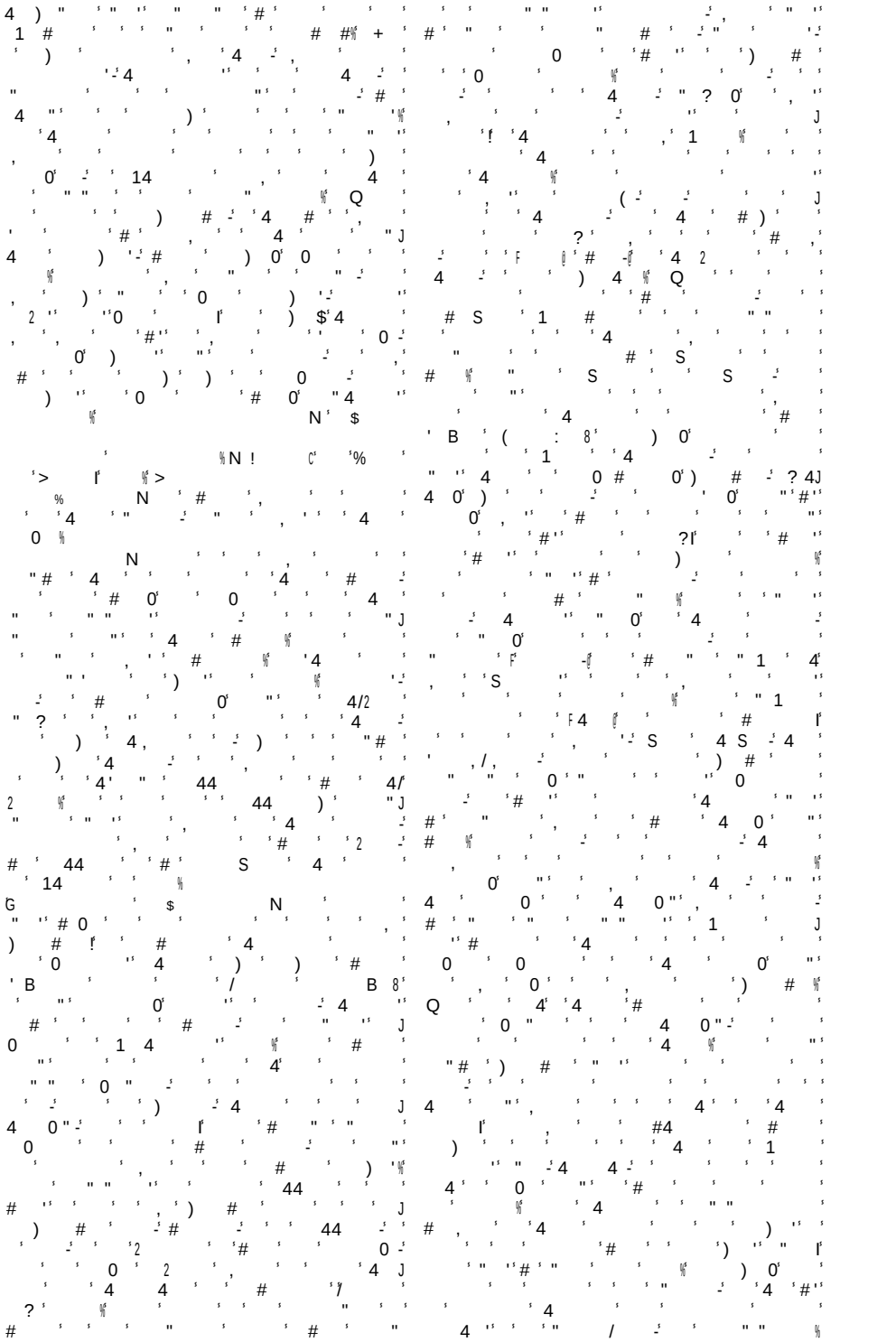

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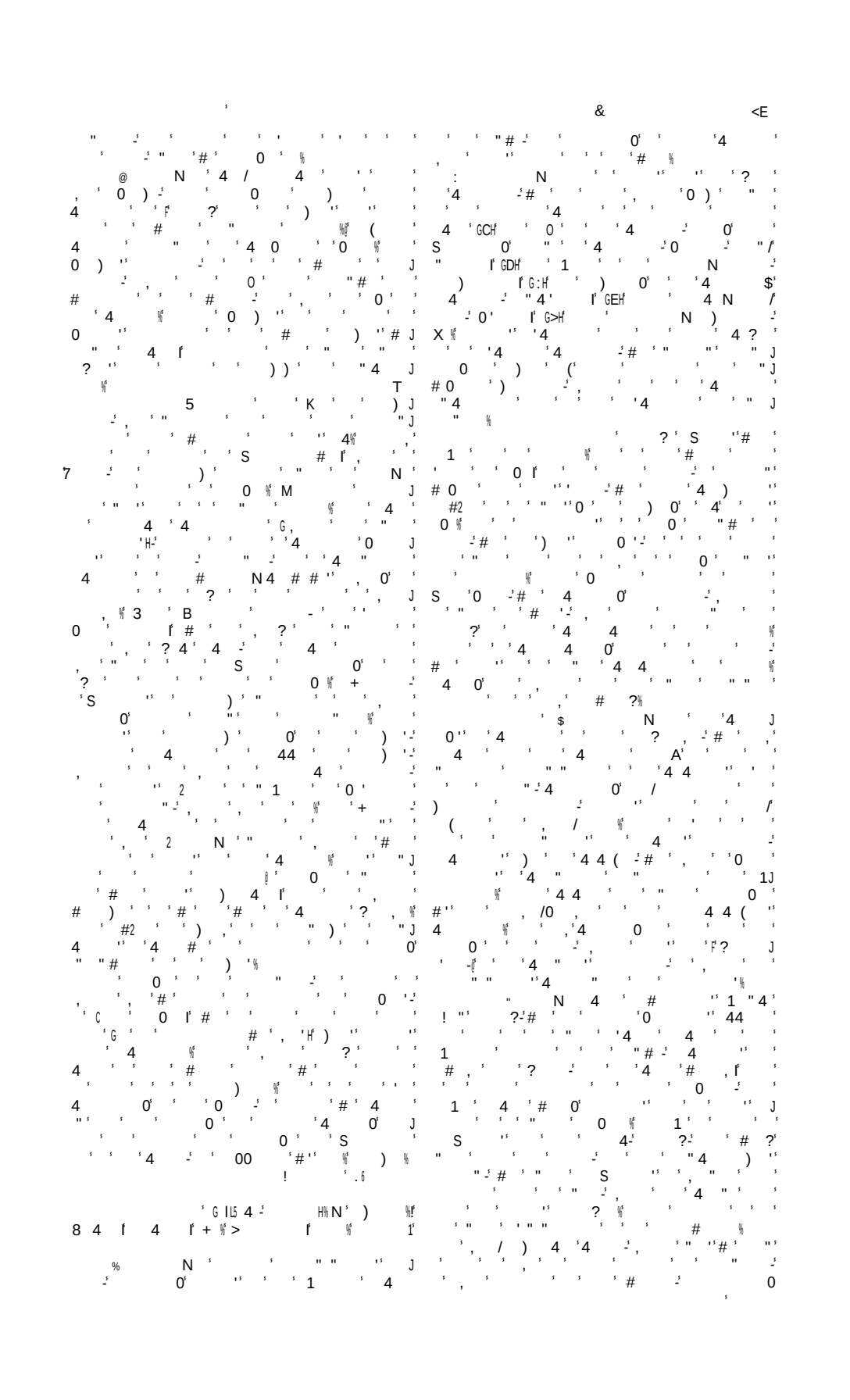

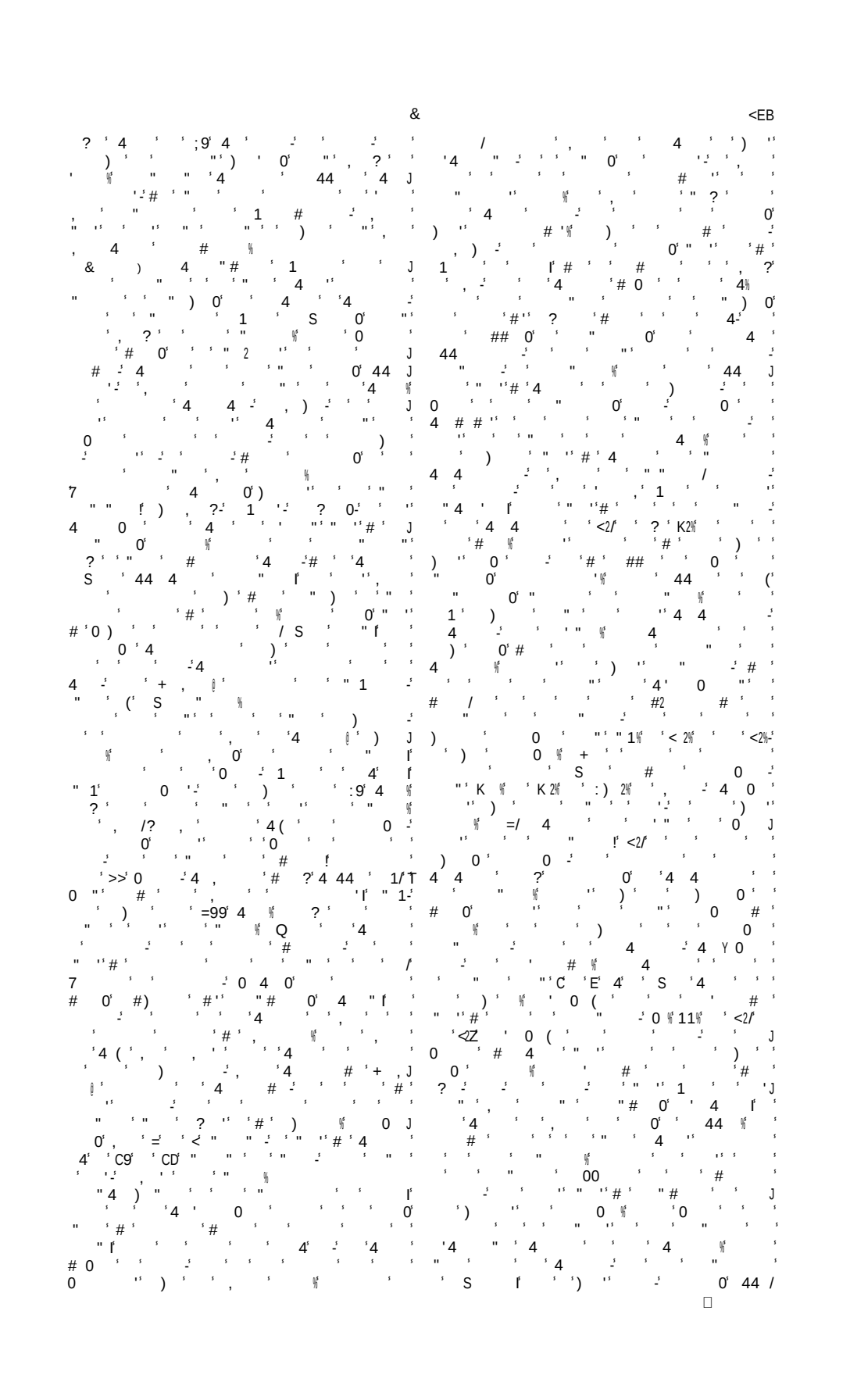

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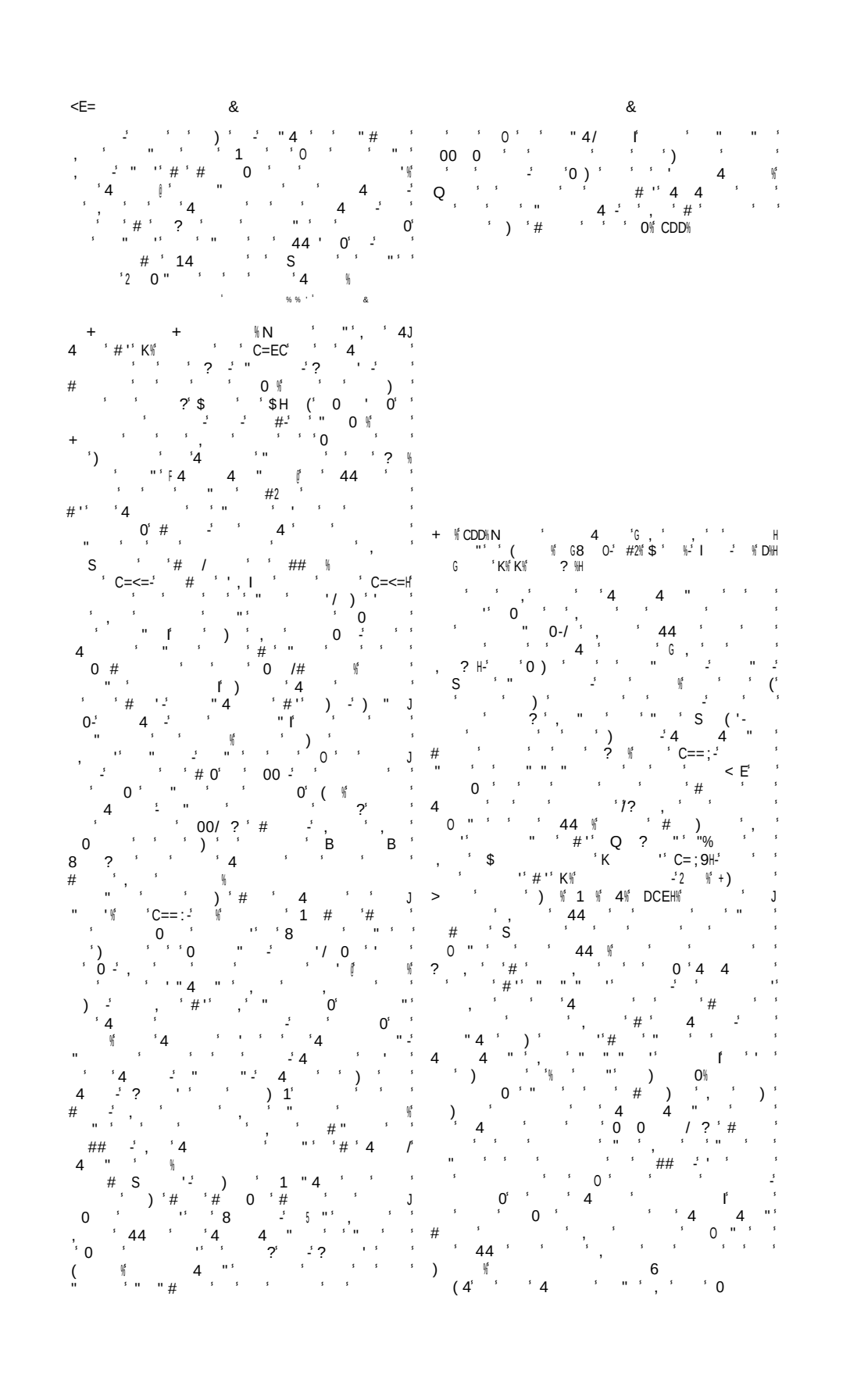

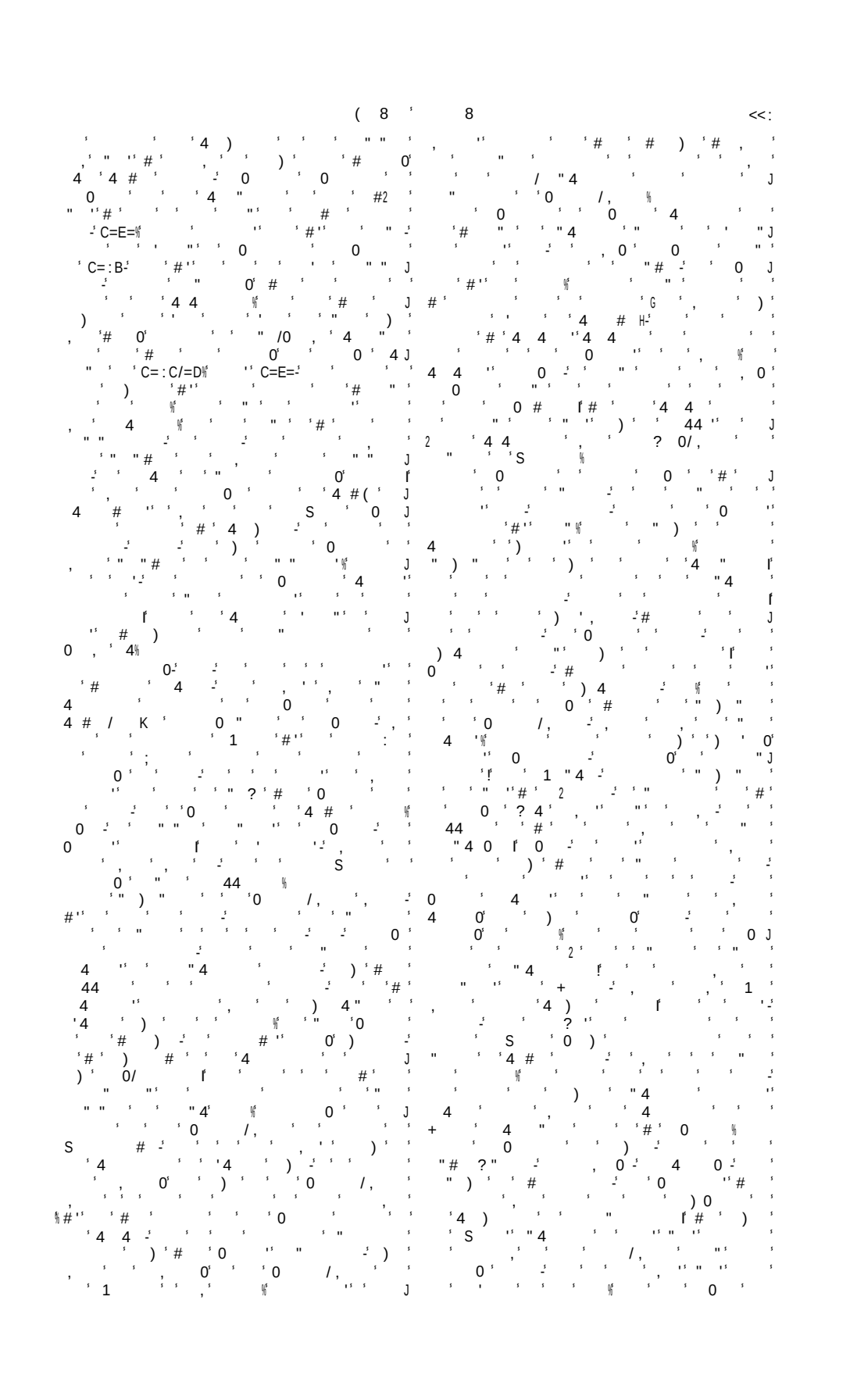

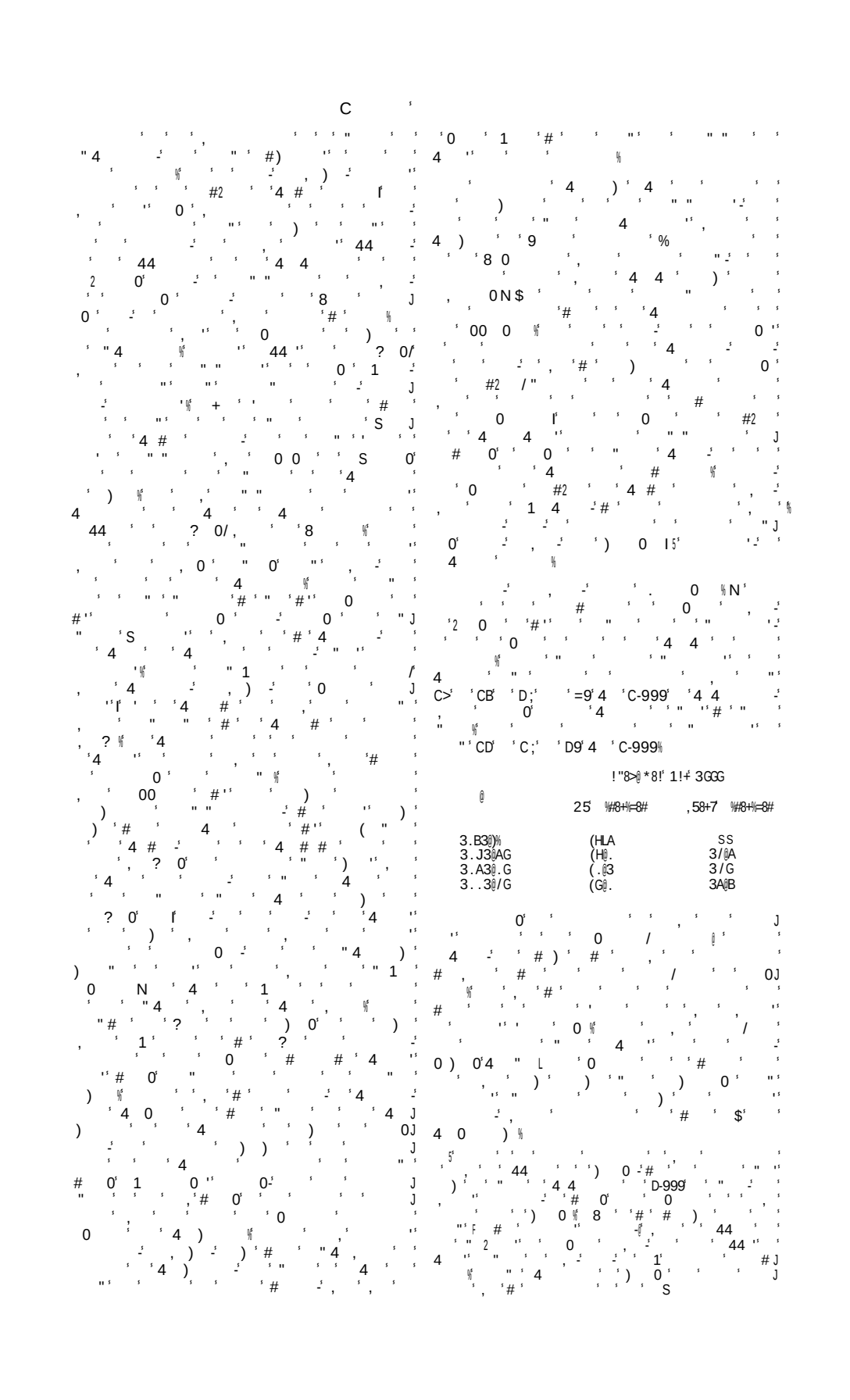

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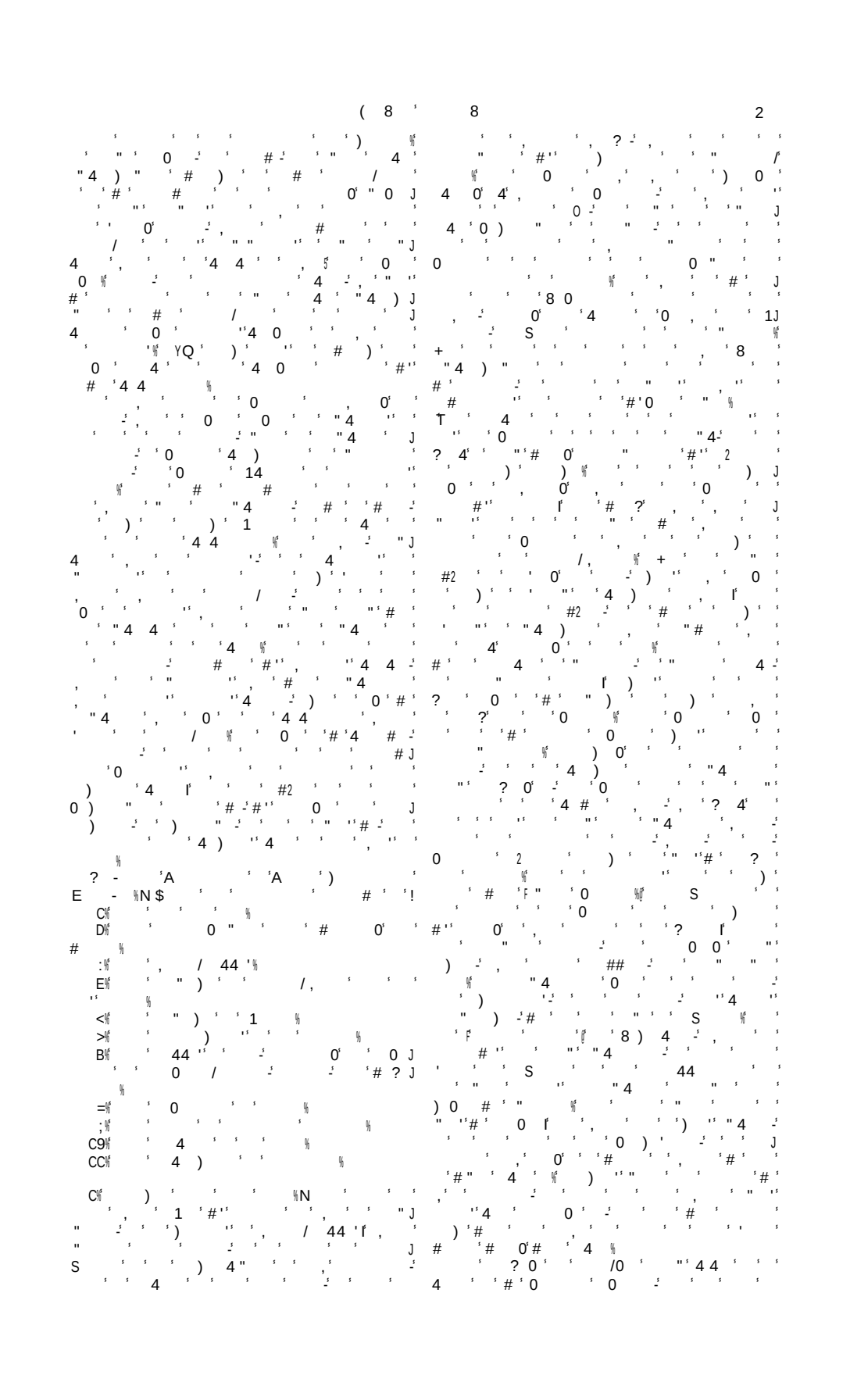

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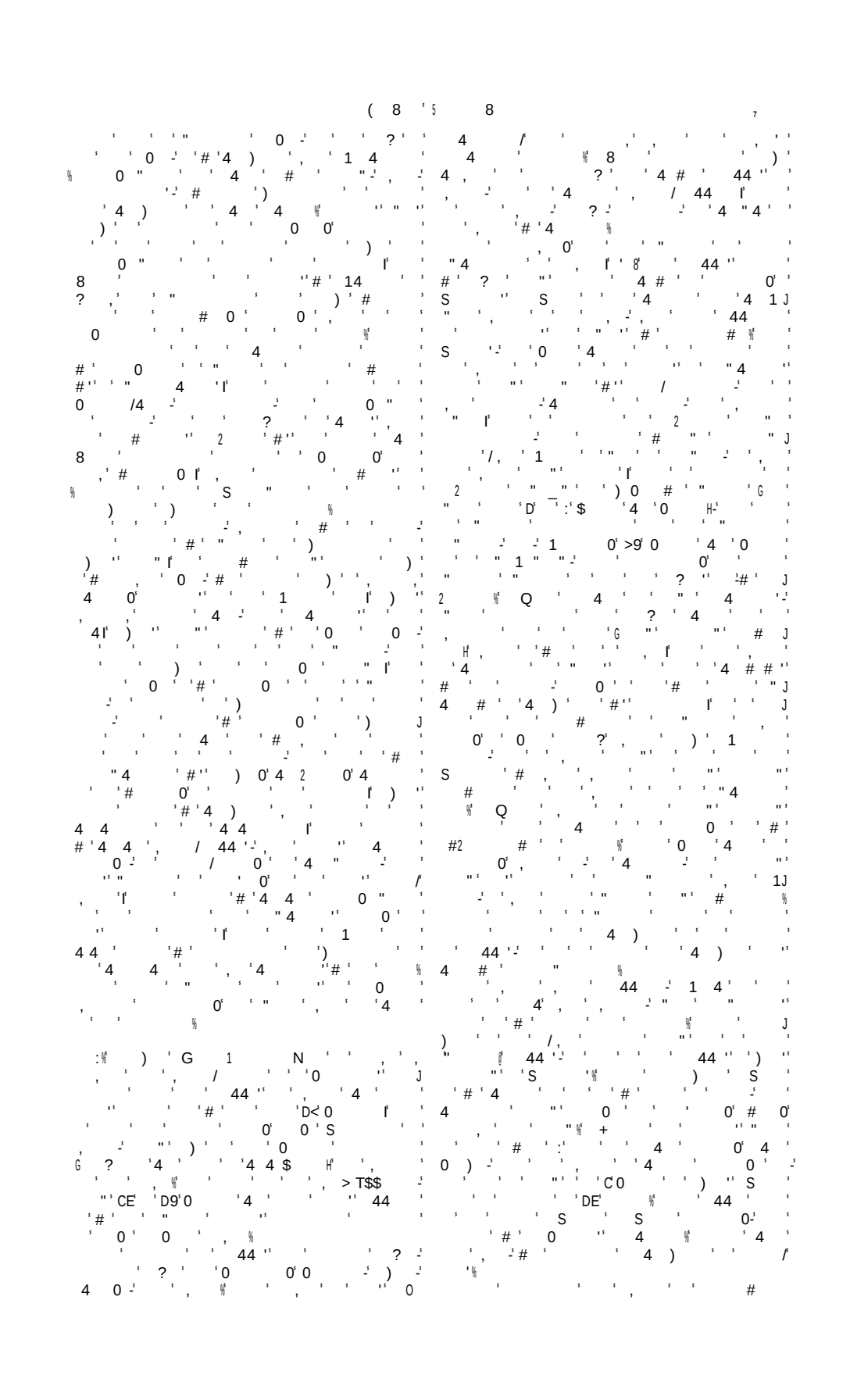

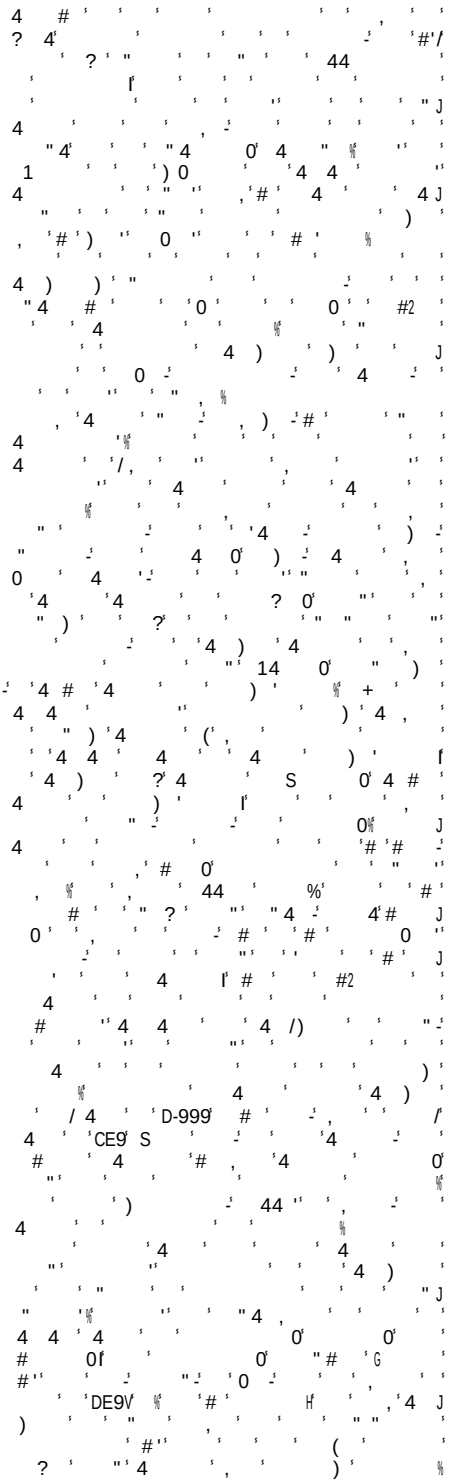

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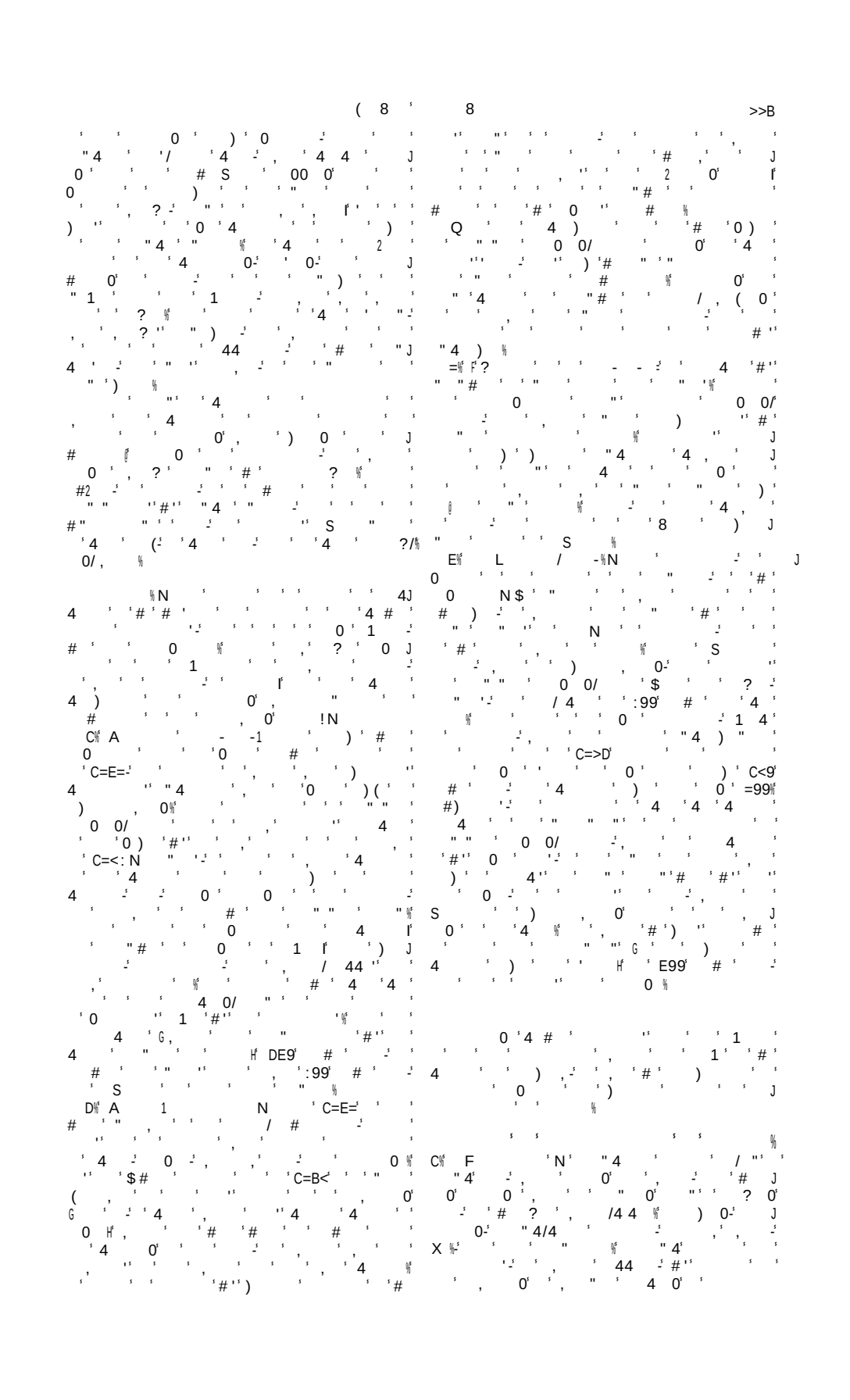

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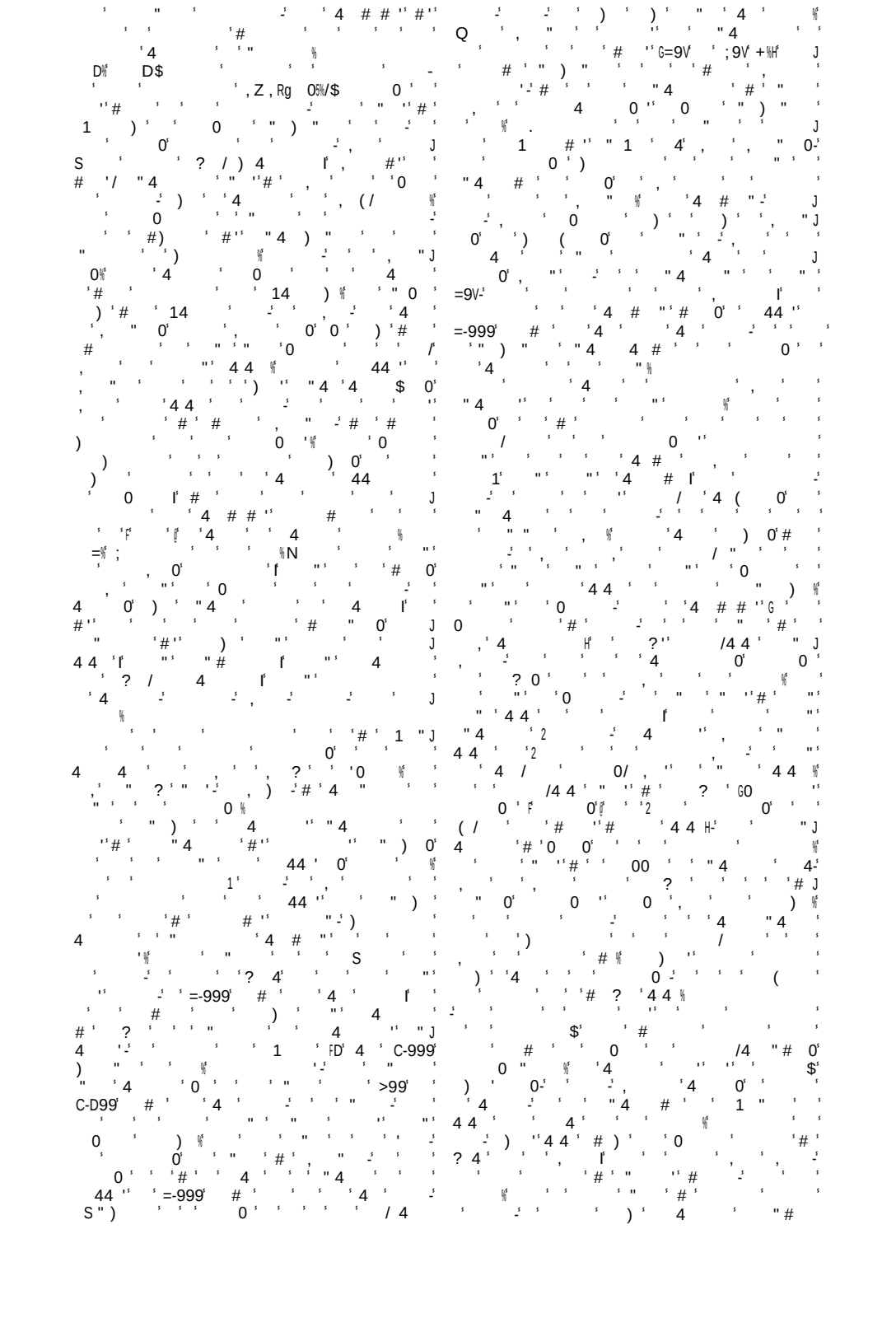

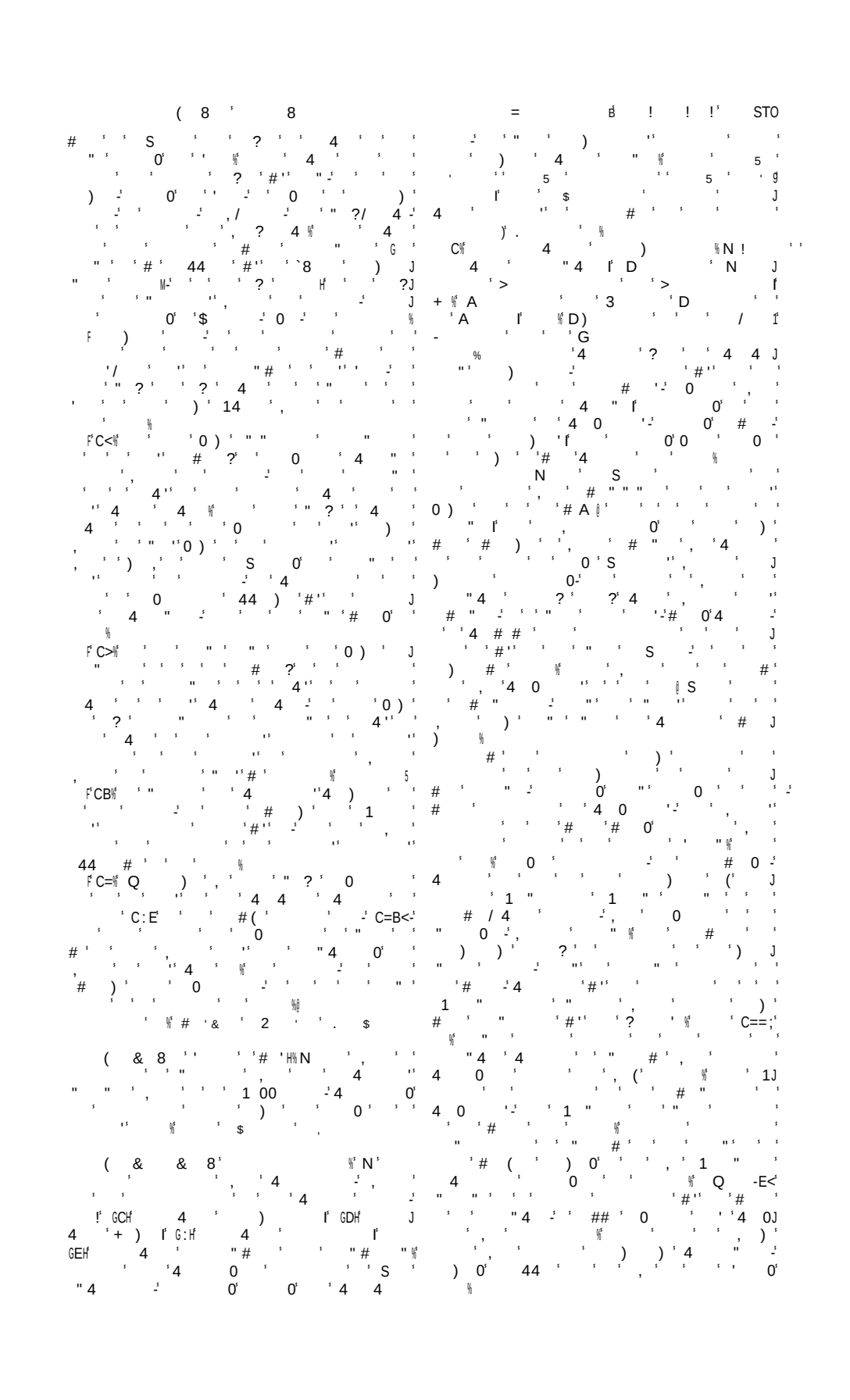

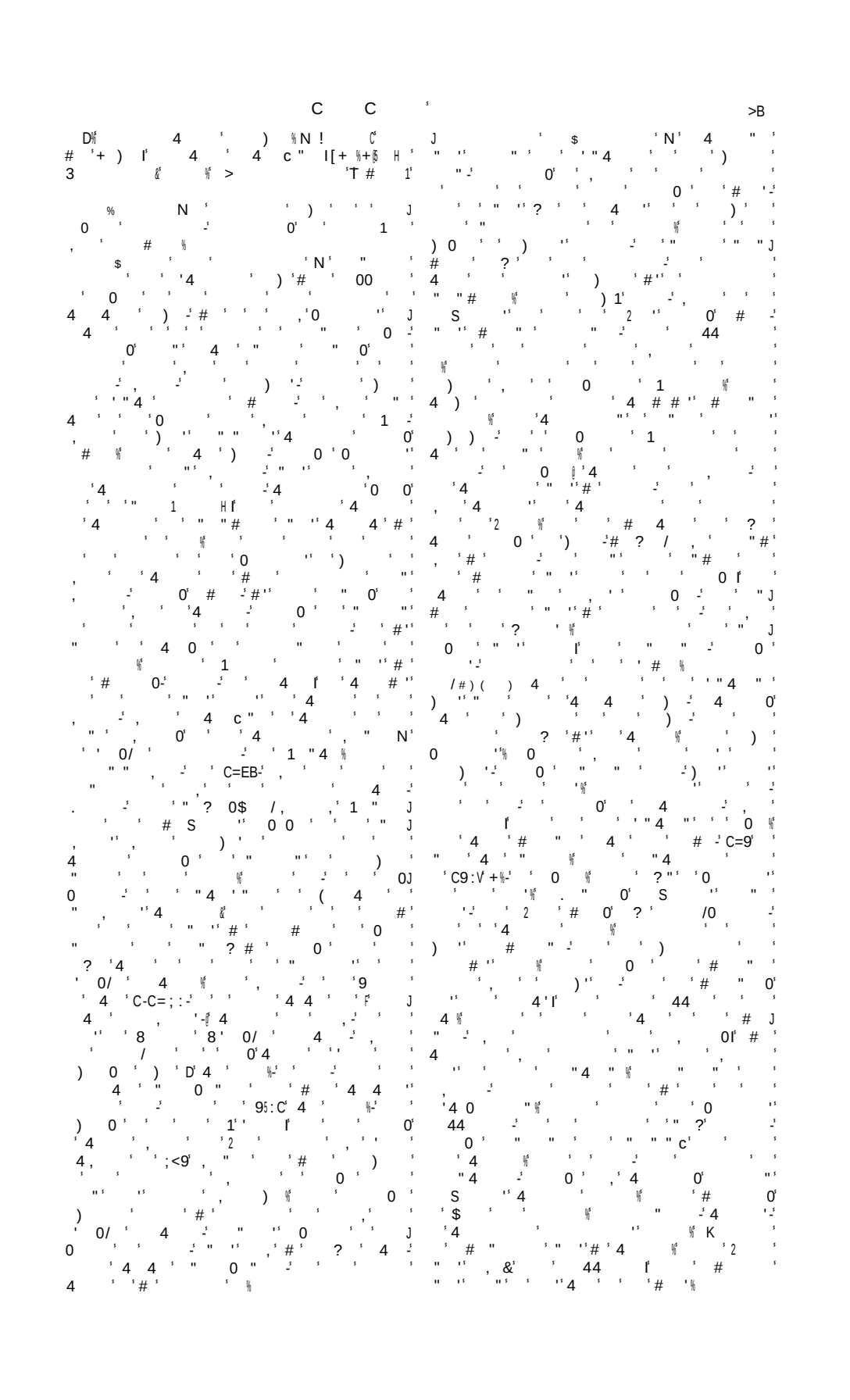

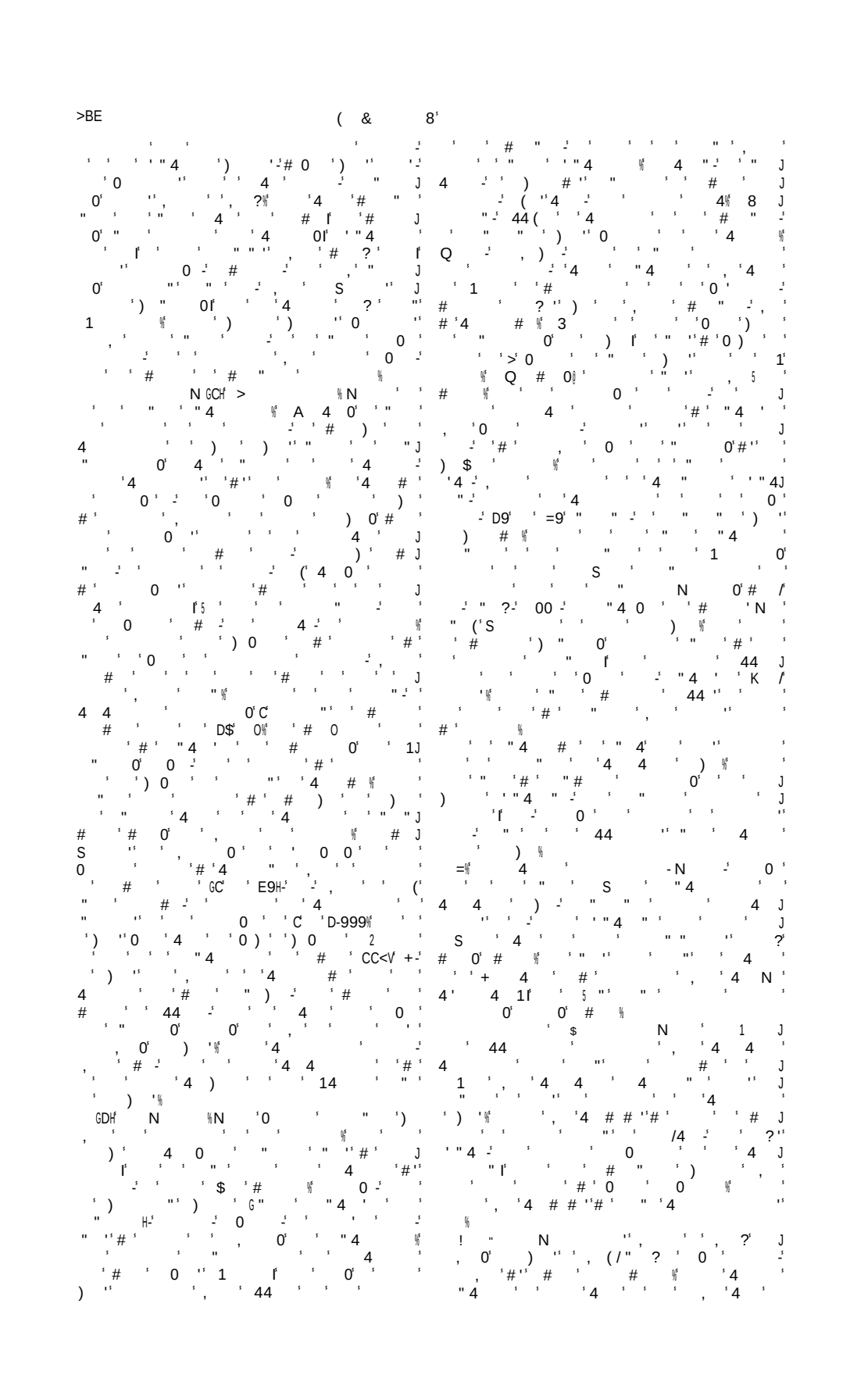

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tidal wave, or predicrotic, or *first secondary wave*, as it is also called, is due to the distension of the arteries, following the increased pressure in the aorta and great vessels, from the reception of the ventricular contents. The *dicrotism*, or *great secondary wave*, is an oscillation of the blood-column, mainly, if not wholly, produced by the rebound of the blood from the closed aortic valves under the pressure of the aortic recoil. *See* DICROTISM.

A pulse-trace (fig. 123) consists then in a *line of ascent*, *a* to *b*, which ends in the *summit wave*, *b*, and corresponds to the first part of the ventricular systole; from the

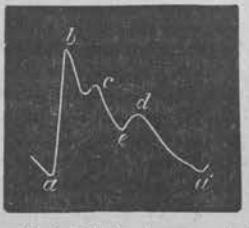


FIG. 123.—Typical Pulse-trace.—*a* to *b*, line of ascent; *b* to *a'*, line of descent; *b*, summit wave; *c*, tidal wave; *d*, dicrotic wave or dicrotism; *e*, aortic notch.

summit wave the tracing falls slightly, till it is again raised by the *tidal wave*, *c*. After the tidal wave a more marked descent occurs, called the *aortic notch*, *e*, and the line again rises, into the *dicrotic wave*, *d*. The *line of descent*, *b* to *a'*, is thus broken by two waves and two notches. The two waves have already been described; of the two notches one precedes the tidal wave, and indicates a slight collapse in the arterial wall after the oscillation called the summit wave; whilst the aortic notch, preceding the dicrotism, marks the fall of pressure in the arteries antecedent to the closure of the aortic valves. The moment these valves are closed the line of descent rises again. It is the bottom of this notch, marking as it does the closure of the aortic valves, which points out the termination of the ventricular systole. The remainder of the line of descent corresponds with the diastole of the ventricle, and is sometimes broken by smaller waves.

The pulse-trace is modified in its chief features by the state of arterial fulness or

FIG. 124.—Trace of Pulse of High Tension.

tension. When the tension is high (fig. 124) the line of ascent is less lofty; the tidal wave is large, nearer to, and sometimes blended with the summit wave; the aortic notch is shallow, and high in the line of descent; the dicrotism is not much developed; and the line of descent is gradual. When the tension is low (fig. 125), the line of ascent is lofty; the summit wave distinct; the tidal wave

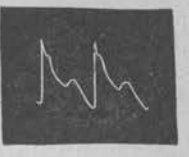
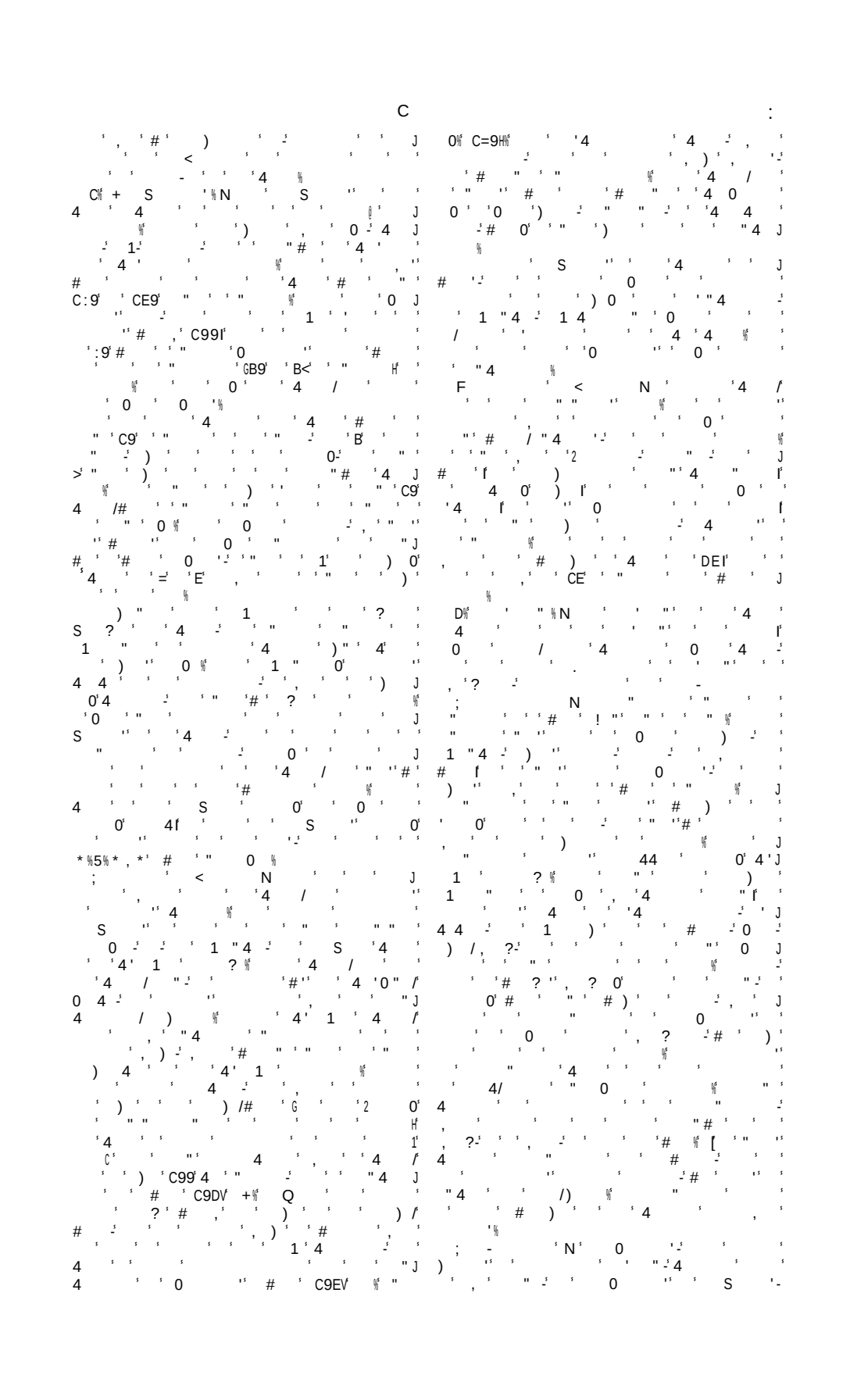


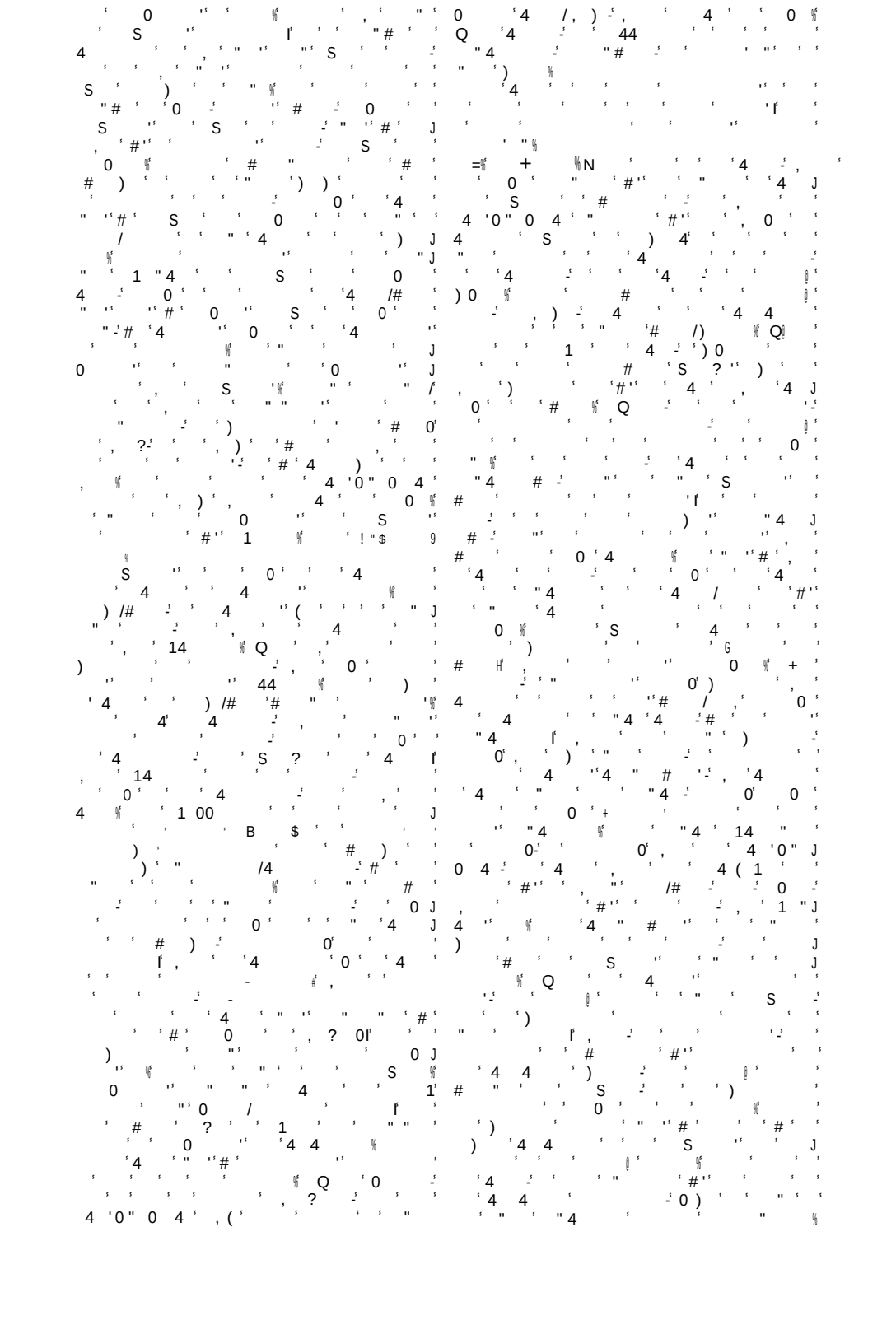
FIG. 125.—Trace of Pulse of Low Tension.

small; the aortic notch deep and low; the dicrotism highly developed; and the line of descent sudden. These modifications are interfered with if the normal elasticity of the arteries be lost, as in arterial degeneration.

The pulse thus registered by the sphygmograph, or felt by the finger, is an oscillation of the blood-column, primarily caused by the heart, but greatly modified by the properties of the blood-vessels. On the heart depend the rate, the rhythm, and, to some extent, the force of the pulse; whilst on the vessels depend the mode of the blood-flow, and the ease of its passage. By virtue of their elasticity, the larger arteries convert the intermittent, jerky impulse, given to the blood by the heart-beats, into an even flow of regular waves; and the smaller arteries regulate, by their permeability, the ease with which the blood-stream flows onward to the veins, thus governing to a great extent the fulness or tension of the arterial system.

The art of feeling the pulse consists in discovering, from the sensation imparted to the finger, the state of the arterial wall and the condition of the arterial contents, as manifested by the frequency, rhythm, and force or tension of the pulse-beat. When the artery is felt to be hard and cord-like, rolling more or less rigidly under the finger, changes in the arterial coats, due to degenerative arteritis or senile change, are indicated, which may render the vessel so rigid as to be practically incompressible. The radial artery is sometimes congenitally anomalous, and a high bifurcation of the vessel or other peculiarity may account for the absence or smallness of the pulse on one or both sides. The finger, as above mentioned, also estimates the fulness of the vessel from its compressibility, and hence learns how the heart and arteries are acting as regards the tension of the pulse. The effects of their action on the form of the pulse-wave the sphygmograph records. In children the pulse may often be most accurately observed in the temporal artery during sleep. *See* SPHYGMOGRAPH (which should be read with this article).





Modern clinical research shows how valuable is a study of this force of the circulation, as manifested by the tension of the arteries. It is this quality of tension which forms the best basis for the division of the various pulse-forms into the two great classes of *hard* and *soft* pulses, or pulses of high and low tension. The hard pulse requires considerable pressure to enable the sphygmograph to record its features to the full; the soft pulse yields the best trace to slight pressure.

Miscellaneous Characters.—The *size* of the pulse depends on the development of the line of ascent and the tidal wave, which are modified by the volume of blood expelled by the ventricle, and the state of fulness of the arteries. When the arteries are contracted, the pulse is small, hard, and wiry; when the coats are relaxed, it is large and soft. The *flickering* pulse is indicative of feeble and unequal ventricular contractions; and the *undulatory* character noticed in some weak pulses is due to the influence of the respiratory movements, causing variations in the tension. The quality of *suddenness* (quick ventricular systole) is betrayed by a nearly vertical line of ascent; while the *gradual* pulse (slow ventricular systole) has an oblique up-stroke.

The following arrangement shows in a small compass the principal varieties of pulse met with in practice, apart from the quality of regularity.

A. Varieties of Hard Pulse—Pulsus durus.

1. The *hard, frequent, sudden,* and *small pulse* of peritonitis, enteritis, and pericarditis :—

Pulsus durus et frequens et celer et parvus, fig. 126.

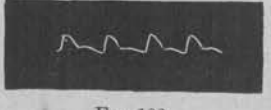


Fig. 126.

2. The *hard, slow, gradual,* and *large pulse* of contracted kidney :—

Pulsus durus et rarus et tardus et magnus, fig. 127.

Fig. 127.

3. The *hard, large,* often *gradual pulse* of cardiac hypertrophy and degeneration of blood-vessels :—

Pulsus durus et magnus et tardus, fig. 128.

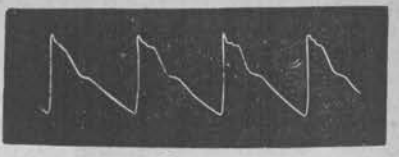


Fig. 128.

4. The *hard, sudden (jerky), large,* and *vibratory pulse* of aortic insufficiency, with strong ventricle :—

Pulsus durus et celer et magnus et vibrans, fig. 129.

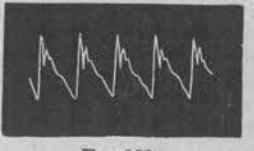


Fig. 129.

B. Varieties of Soft Pulse—Pulsus mollis.

1. The *soft, frequent pulse* of pyrexia; dicrotous, fully dicrotous, and hyperdicrotous pulses :—

Pulsus mollis et frequens, fig. 130.

Fig. 130.

LIBRARY OF THE BOMBAY BRANCH OF THE ROYAL ASIATIC

2. The *soft, frequent,* and *large pulse* of rheumatic fever :—

Pulsus mollis et frequens et magnus, fig. 131.

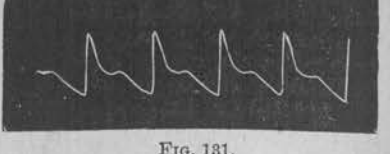


Fig. 131.

3. The *soft, small, frequent,* and *sudden pulse* of debility :—

Pulsus mollis et frequens et parvus et celer, fig. 132.

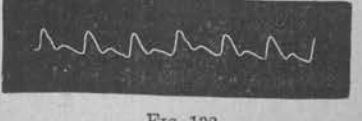


Fig. 132.

4. The *soft, frequent,* and *small (running) pulse* of collapse in fever:—

Pulsus mollis et frequens et parvus, fig. 133.

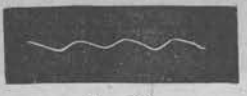


Fig. 133.

B. Walter Foster.

PUPIL, Disorders of the.—Synon.: Fr. *Troubles de la Pupille*; Ger. *Stöhrungen der Pupille.*

Anatomy and Physiology.—The pupil is the approximately circular aperture situate a little to the nasal side of the centre of the iris. Responsive to the various influences which cause contraction and relaxation of the muscular and elastic tissues and blood-vessels of the iris, the pupil serves to regulate the amount of light entering the eye, and to correct some of the spherical aberration of the refracting media. In health, and when the lids are open, both pupils undergo frequent and equal variations in size: *contracting* when a bright light falls upon the eyes, and when the eyes converge or are accommodated for near objects; *dilating* when the light is feeble or the eyes are shaded, and when the accommodation is relaxed and the eyes are directed to some distant object. They also dilate when the skin is pinched, or when the cutaneous or other sensory nerves are stimulated, and in some psychical and emotional states. Fine oscillations occur synchronously with the beatings of the heart, and others with the movements of respiration. Variations in the size take place in many other physiological states. During muscular exertion, and as the result of fatigue, the pupils dilate; in deep sleep they contract. The pupils of both eyes contract and dilate together, even when only one eye is stimulated. The movements of the iris are involuntary, but, being coördinated with changes of accommodation, they are brought indirectly under the influence of the will.

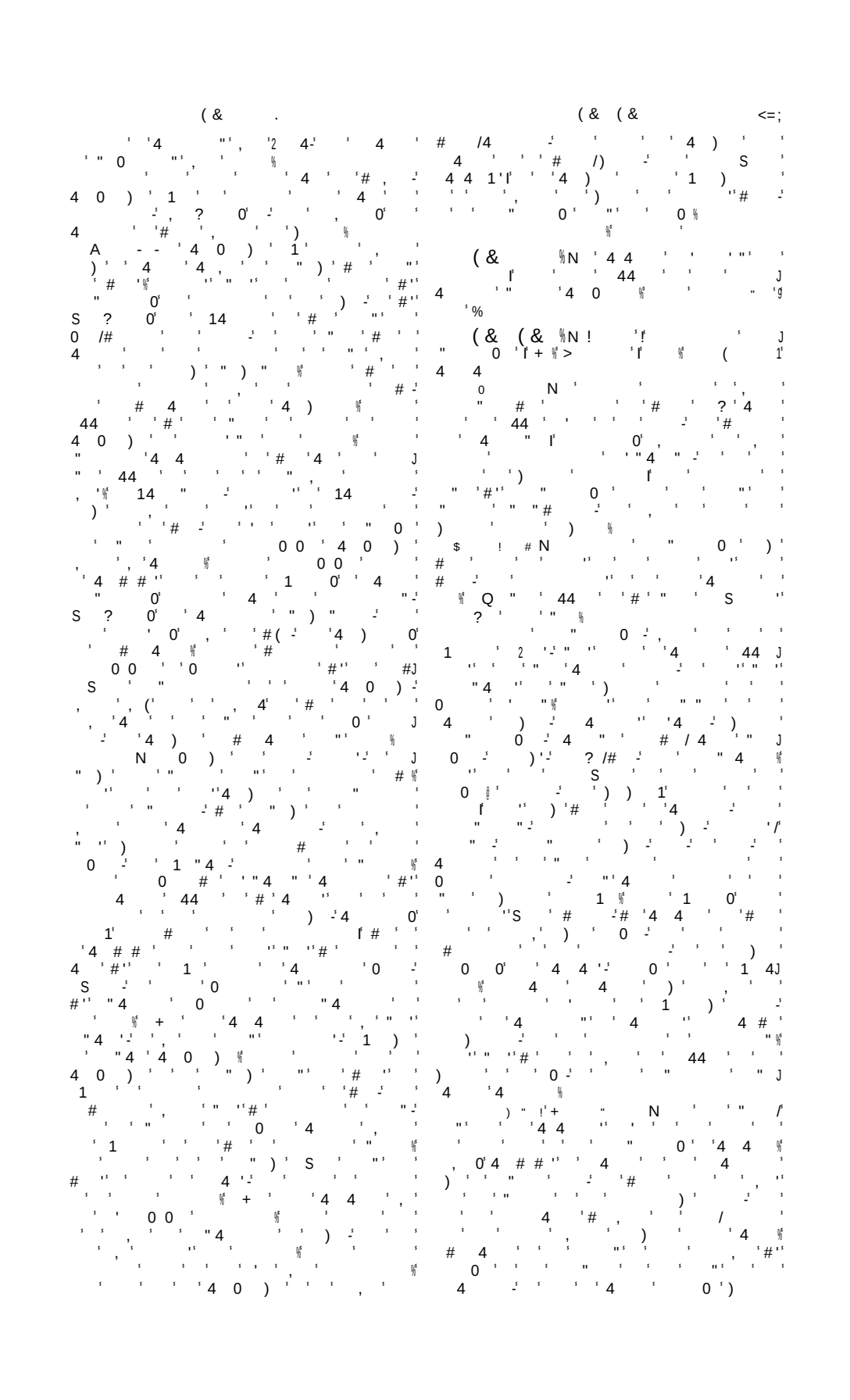
The *size* of the pupils differs in different individuals, and in the same individual at different periods of life, and in different states of health and nutrition. The pupils are very small in newly born babes, larger in children and young adults, and smaller again in old persons. They are generally larger in myopic eyes, and in persons with dark irides; smaller in hypermetropes, and in persons with fair or blue irides. The size may range in health from 2·5 mm. to 6 mm.

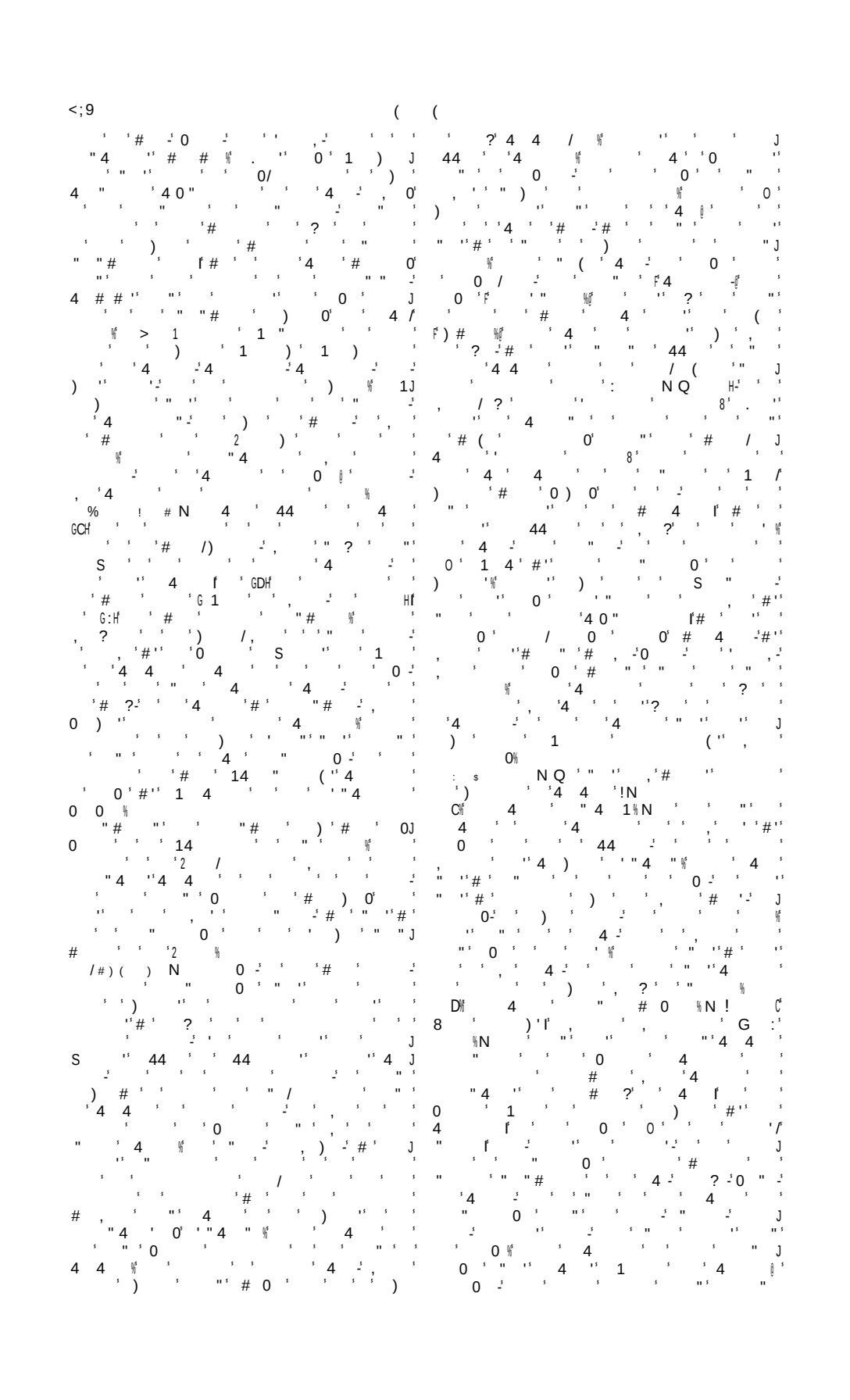
A closer examination of the variations in the size of the pupil, and of the circumstances under which they take place, shows that some of the movements of the iris are 'reflex,' some are 'associated,' and some are 'consensual.' The contraction to the direct stimulation of light is reflex, as is also the dilatation which occurs on stimulation of the cutaneous nerves. The contraction which takes place during convergence or accommodation is associated; while the harmonious and equal action of both pupils when only one eye is stimulated is consensual.

The contracting mechanism of the iris is innervated by the third cranial nerve; the dilating mechanism by the cervical sympathetic. At the pupillary margin of the iris is a ring of plain muscular tissue (sphincter iridis); and in the expanse of the iris, and lying between the vascular and the posterior pigment layers, is a thin elastic lamina composed of long oval or rod-shaped nuclei, and radially disposed. Some authorities regard this lamina as muscular (dilator iridis), whilst others deny its muscular character. Constriction of the pupil is produced chiefly by the contraction of the sphincter muscle, though it is augmented by the turgescence of the blood-vessels of the iris. The dilatation of the pupil is perhaps less simple. It may be due to contraction of the dilator muscle. Those who deny the existence of this muscle ascribe the dilatation to the inhibitory influence exerted by the sympathetic nerves upon the sphincter muscle. According to this view, dilatation is a complex act due partly to relaxation of the sphincter, partly to the elasticity and resiliency of the iris, and partly to the depletion of its blood-vessels.

The *contraction* which takes place when light falls upon the eye is a reflex act, of which the optic nerve is the afferent path; while the efferent path is that portion of the third cranial nerve which passes through the lenticular ganglion, and enters the eye with the *short* ciliary nerves. The 'centre' is the anterior portion of the elongated nucleus of the third nerve, which lies in the front part of the floor of the aqueduct of Sylvius. From the anterior extremity of this nucleus arise also the motor fibres which govern the muscle of accommodation; and the community, or at least contiguity, of these two centres helps to explain the 'association' of contraction of the pupil with accommodation. It is, however, still uncertain how the afferent fibres reach the constrictor centre; but it would seem that these fibres are not the same as those which subserve vision, and that indeed they leave the optic path either at the chiasm, or at some other part of the tract before the visual centres are reached. The 'consensual' reaction of the pupil is accounted for partly by the incomplete decussation of the optic nerve at the chiasm, and partly by the communication (coupling) between the centres of the third nerves of the two sides, whereby the constrictor apparatus of the two eyes become functionally connected.

The *dilating mechanism* is governed by





Rodents are highly susceptible, and hence are commonly used for test-inoculations.

Although apparently endemic in certain regions, there can be little doubt that this is due to the great persistence of the contagium by means of its spores, and that the recurrence of outbreaks in cattle is due to the careless disposal of carcasses of animals which have died of the disease.

In man, the disease is usually traceable directly to inoculation from the carcass, or from parts, such as the skin or hair, which have been kept in a dry state. Hence butchers, shepherds, and stockmen, who flay the carcass or bury it, are most commonly its victims from the more direct mode of inoculation; whilst wool packers and sorters, horsehair cleaners, workers in felt manufactories, furriers, tanners, and the like, are exposed to the less direct form. But in rarer instances no such mode of contagion can be traced, and it is probable that in these the poison has been conveyed by flies, or similar agencies. The flesh of the dead animals can rarely be suspected, unless it is eaten raw or very imperfectly cooked. Even then, as we know from experiment, large quantities of the bacillus or its spores may do no harm. Butter and milk are alleged by Heusinger to be possible carriers of the poison. Nor is it improbable that the use of water which has been contaminated by wool-waste, bone-dust, or other substances, may convey contagion to cattle. But none of these modes is proved to be common in man, and the spread of contagion from one human subject to another is extremely rare.

It will, however, be shown that in man the disease may be acquired either by inoculation or by inhalation of the dust containing the spores of the bacillus, perhaps also by swallowing them.

Description. — The form of the disease depends on the mode of entrance, and may be internal or external.

Anthrax in Cattle.—This will be briefly described, as of importance in relation to man. Whereas in some animals there are marked external manifestations, either pustular or of the nature of diffuse phlegmonous swellings, with glandular enlargement, such conditions are rare in cattle. In them there may be not only no external changes, but even few perceptible symptoms. Only for a few hours before death there may be evident languor, loss of appetite, and then stupor. But sometimes animals may be found dead in the morning which had been apparently well the night before. If, however, they are carefully observed, it is usually found that there is marked rise of temperature, followed by coldness and lividity before death.

On examining the carcass, the blood is often found fluid, and may be dark in colour. Sometimes there are glandular swellings and inflammatory œdema, especially around the pharynx, œsophagus, and stomach. But these are more frequently absent, and there are only scattered hæmorrhages here and there, especially in the lungs and heart-wall, and sometimes in the submucous tissues.

The most constant and characteristic condition is the enormous swelling of the spleen, which is engorged with blood, and readily breaks down on slight handling. This splenic enlargement, be it remembered, is constant only in cattle, and may be entirely absent in other animals, or very slight and irregular.

Microscopic examination shows enormous numbers of anthrax bacilli in the blood, especially in the spleen, lungs, and, next in frequency, in the capillaries of the glomeruli of the kidneys, and sometimes in the liver. In these organs many of the capillaries may appear to be completely filled at parts with bacilli.

It is very important to bear in mind that this abundance and this distribution of the bacilli are very inconstant in other animals. Only guinea-pigs show a similar condition with any constancy. In other animals the bacilli may be few and scattered, being found

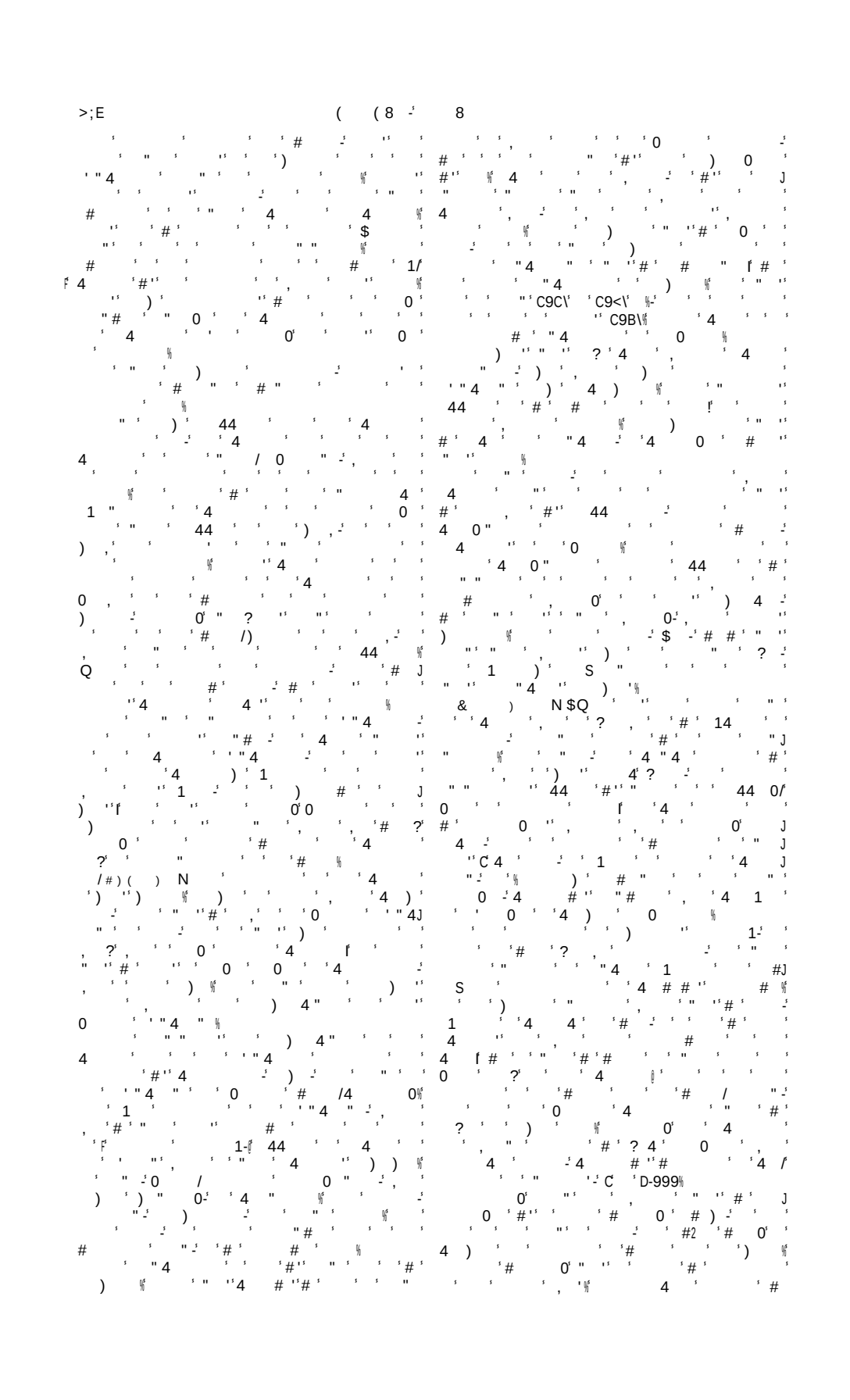
Fig. 134.—Part of the Spleen of a Guinea-pig which died of anthrax, showing the relative proportion of bacillus rods and leucocytes. × 100 diam. From a photomicrograph.

especially in the capillaries of the lungs and kidneys ; or they may be mainly limited to the lymphatics, including the glands and lymph cavities. Hence, whilst all parts of the body of cattle which have died of the disease are actively poisonous, it may be difficult to convey the disease from other animals except by inoculation of the fluid from the more affected parts.

Moreover, the activity of the bacillus is rapidly destroyed by decomposition, so that no results may be produced by inoculation from the dead animal when decomposition has set in, unless spore-formation has occurred. This is also true of the human subject.

Spore-formation is sometimes alleged not to occur during life. It may, however, do so in the kidney, if the bacilli pass into the urinary tubules, and also in serous exudations in the pleura and elsewhere, either before or very speedily after death.

Destruction of the carcasses by fire or by



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infiltration of the whole of the connective tissue around them is present, reaching sometimes up into the neck.

The fluid squeezed from this tissue may contain scanty bacilli, but both here and in the pleural fluid they may be very scanty.

On opening the trachea and bronchi, they are found to contain blood-stained frothy fluid. Towards the lower part of the trachea and in the main bronchi the mucous membrane is irregularly swollen and blood-stained in patches. In addition, hæmorrhages are seen in the mucous membrane, forming raised spots. This condition is usually limited to the main bronchi, but may extend into their primary divisions.

On microscopic examination, the most marked changes correspond to the hæmorrhagic areas. The hæmorrhage lies for the most part immediately beneath the basement-membrane, which may have ruptured,

FIG. 135.—Anthrax Bacilli. *a*. In heart-wall of a cow. *b*. In the pulmonary capillaries of a cow. *c*. In the human bronchial mucous membrane, in a case of 'wool-sorter's disease.' × 800 diam.

the blood forming a layer beneath the detached epithelium. It may also penetrate deeply into the mucous and submucous coats. All the tissues beneath and around are infiltrated with serum, and their tissue-elements thus separated, but not usually necrotic. The blood-vessels are dilated, but leucocyte exudation is scanty. Dense masses of bacilli are found in the exudation, and escaping to the surface. They also surround and extend in the lymphatics, perivascular and other, and may be traced in them to the deeper lymphatic plexuses. Similar masses of bacilli may also be seen in the superficial layers of the mucosa, where as yet little or no inflammation has occurred. They often lie immediately beneath the basement-membrane. Little or no catarrhal change is seen, the epithelium simply desquamating; if catarrh is present, it is usually of older date.

In the bronchial glands, the condition is often masked by the extensive hæmorrhage. Bacilli are found, often scantily, especially in the lymph-sinuses of the cortex. Sometimes they are very abundant, and may then also appear in the capillaries.

In the lungs, scattered patches of hæmorrhage may be present, mainly due to the inhalation of blood from the bronchi. These may also produce areas of lobular collapse and broncho-pneumonia. But for the most part, nothing but the general collapse and congestive œdema are found in the lungs, and bacilli are often not to be discovered, except here and there in the lymphatics near the root. This common absence of bacilli in the pulmonary capillaries proper is in marked contrast with the condition usual in cattle.

In other organs, the changes are diverse, and may be absent. There is not usually much cloudy swelling or other indication of septicæmia, though they may be present.

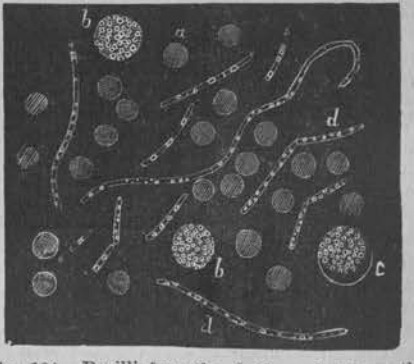
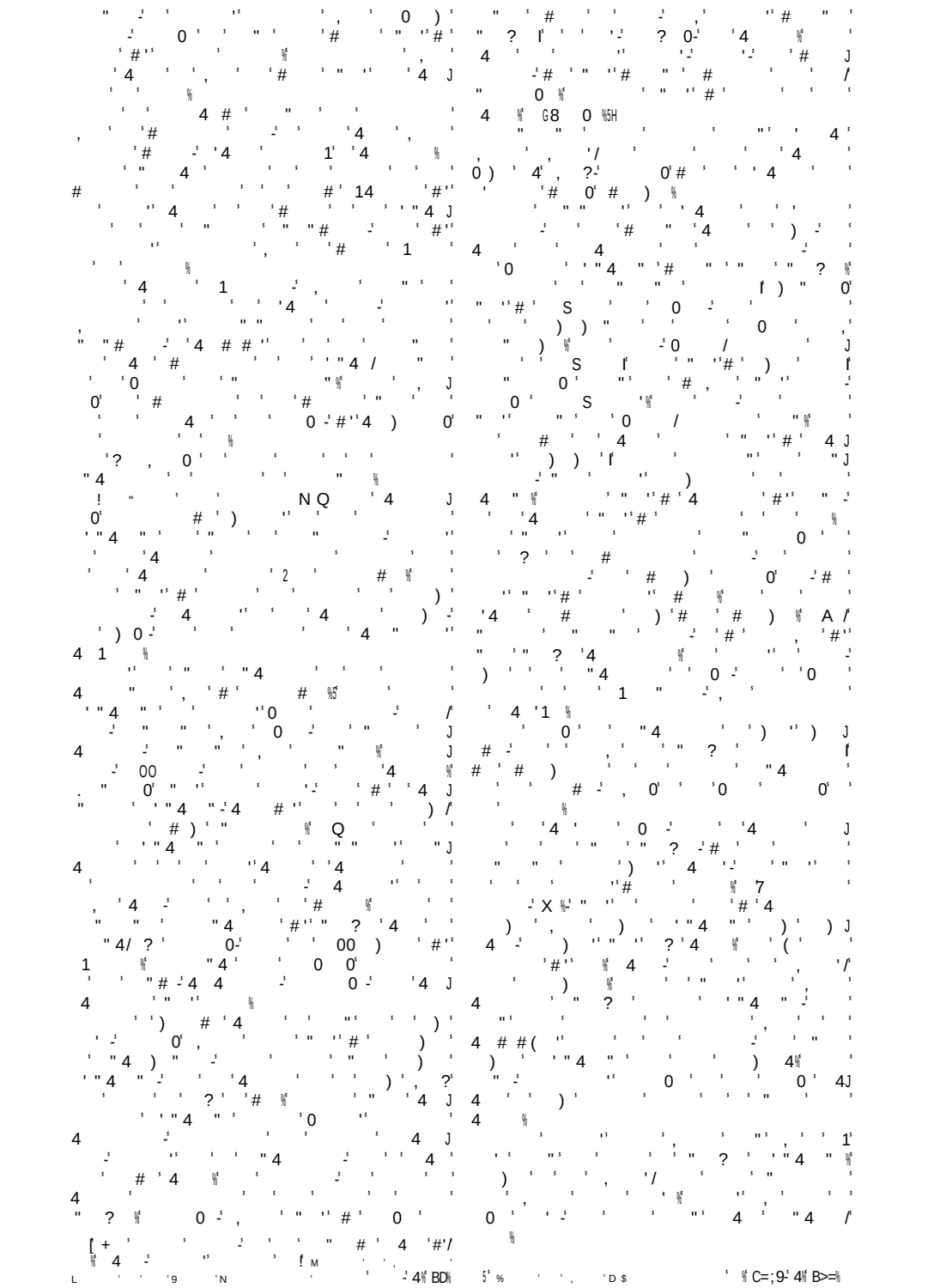


FIG. 136.—Bacilli from the fluid exuded from the lung in a case of internal anthrax. *a*. Red blood-corpuscles. *b* and *c*. Large granular corpuscles from the lung. *d*. Bacilli of various lengths, containing highly refracting granules, or fully formed spores. × about 700 diam.

Minute hæmorrhages are often apparent; or, in the pia mater, and generally in serous membranes, diffuse extravasations. In the stomach and intestines submucous exudation and scattered hæmorrhage may occur.

For the most part, the spleen is but slightly swollen. Examination of the blood and of other organs, such as the kidney, in which bacilli are commonly abundant in many



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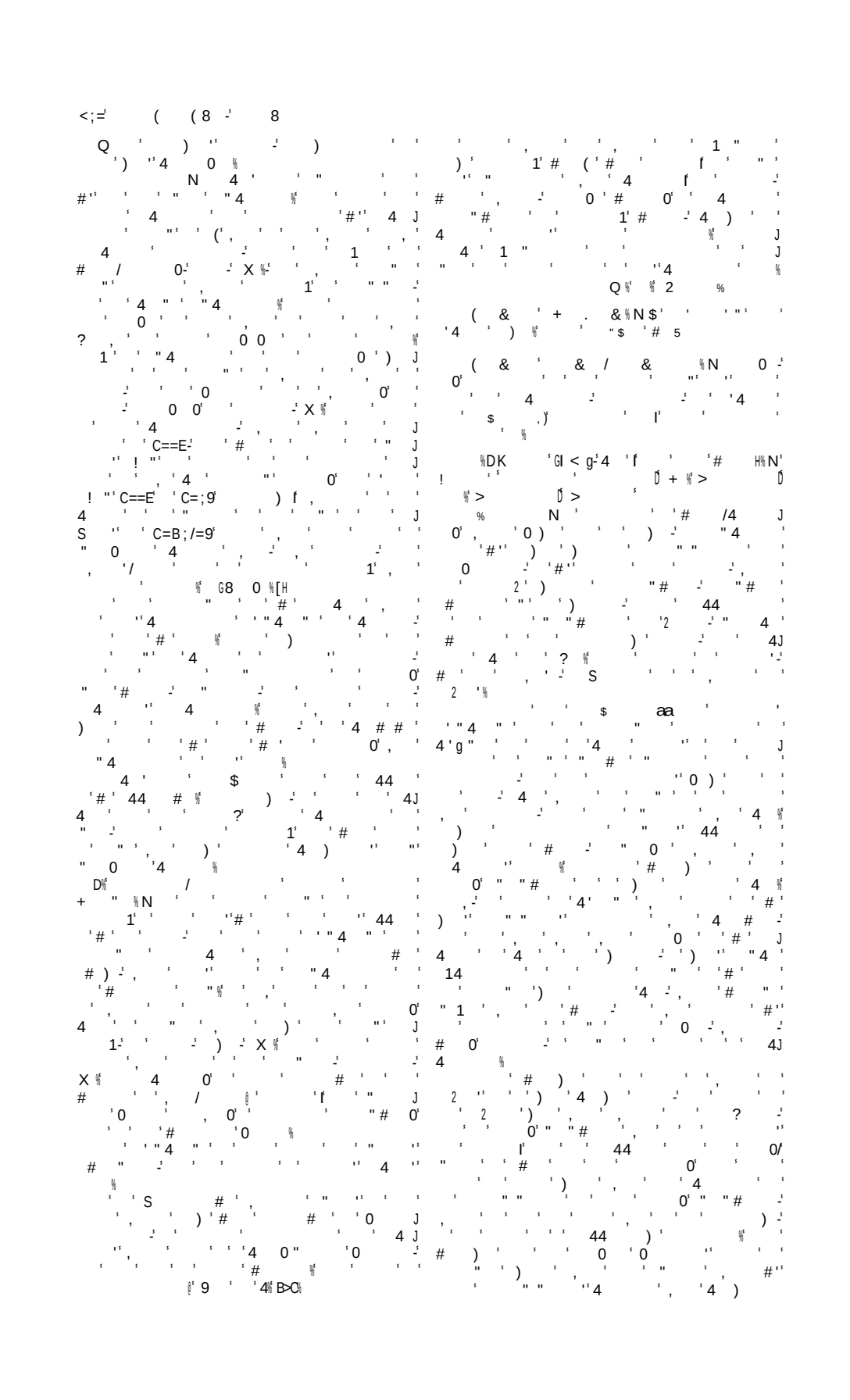

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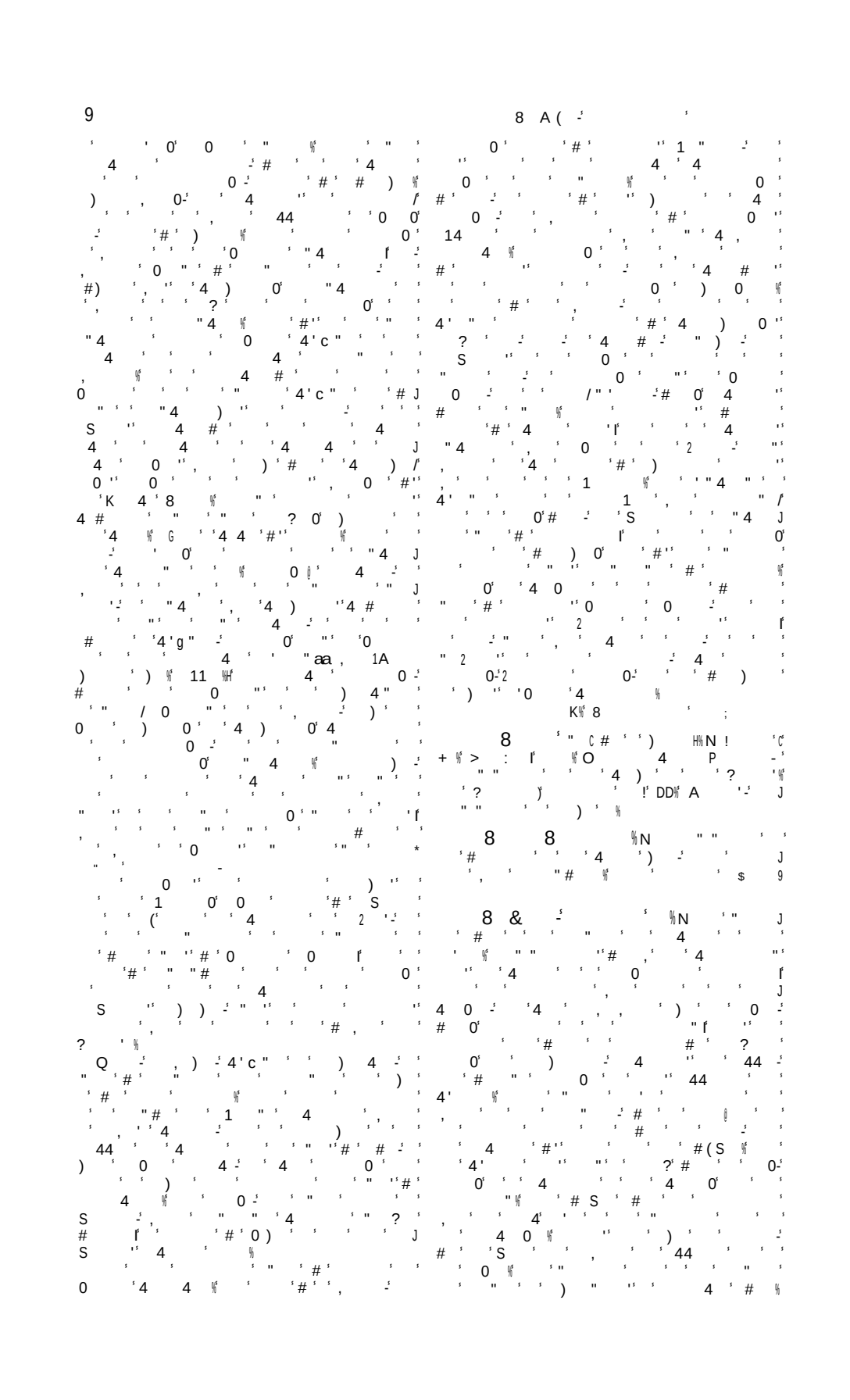

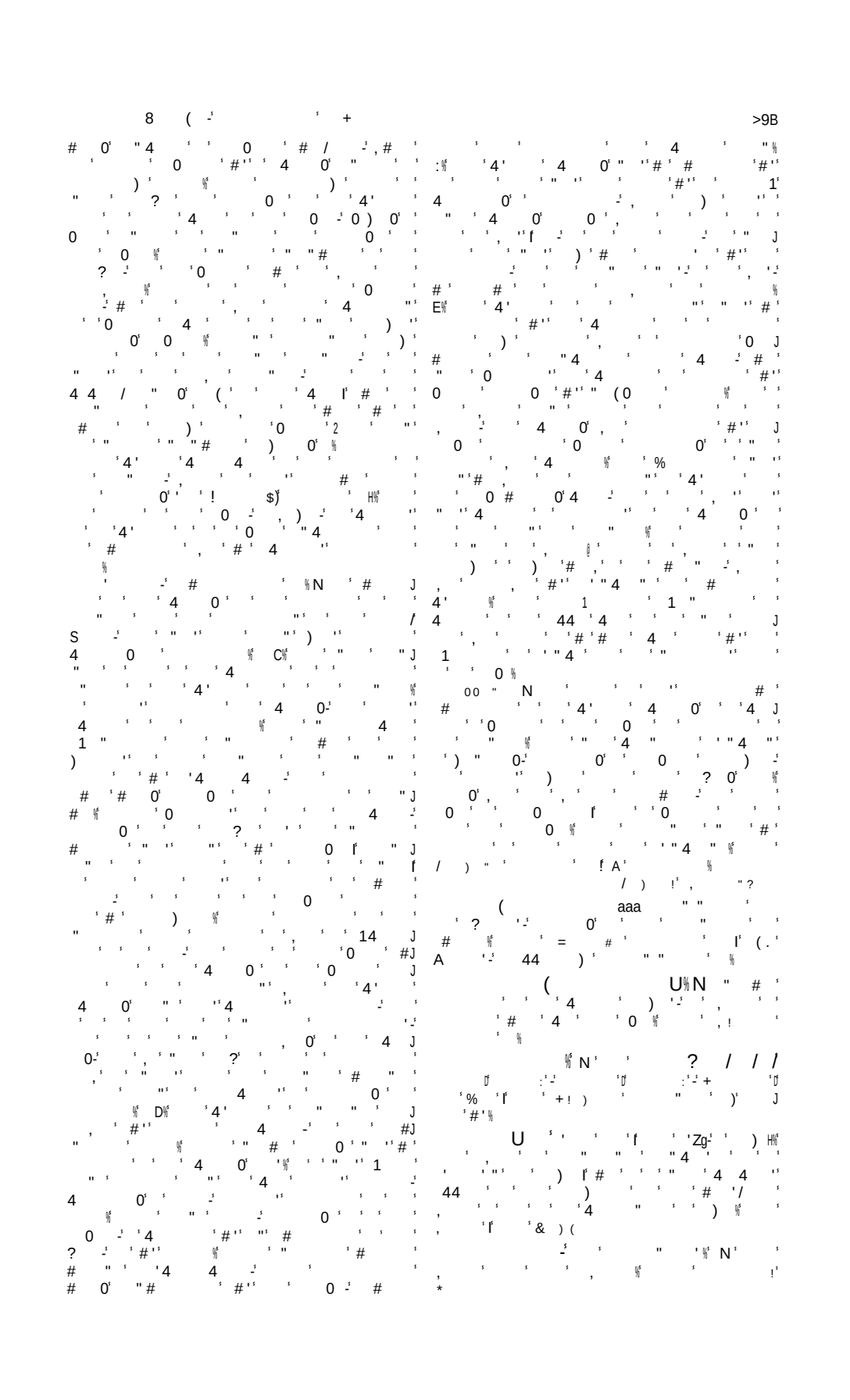

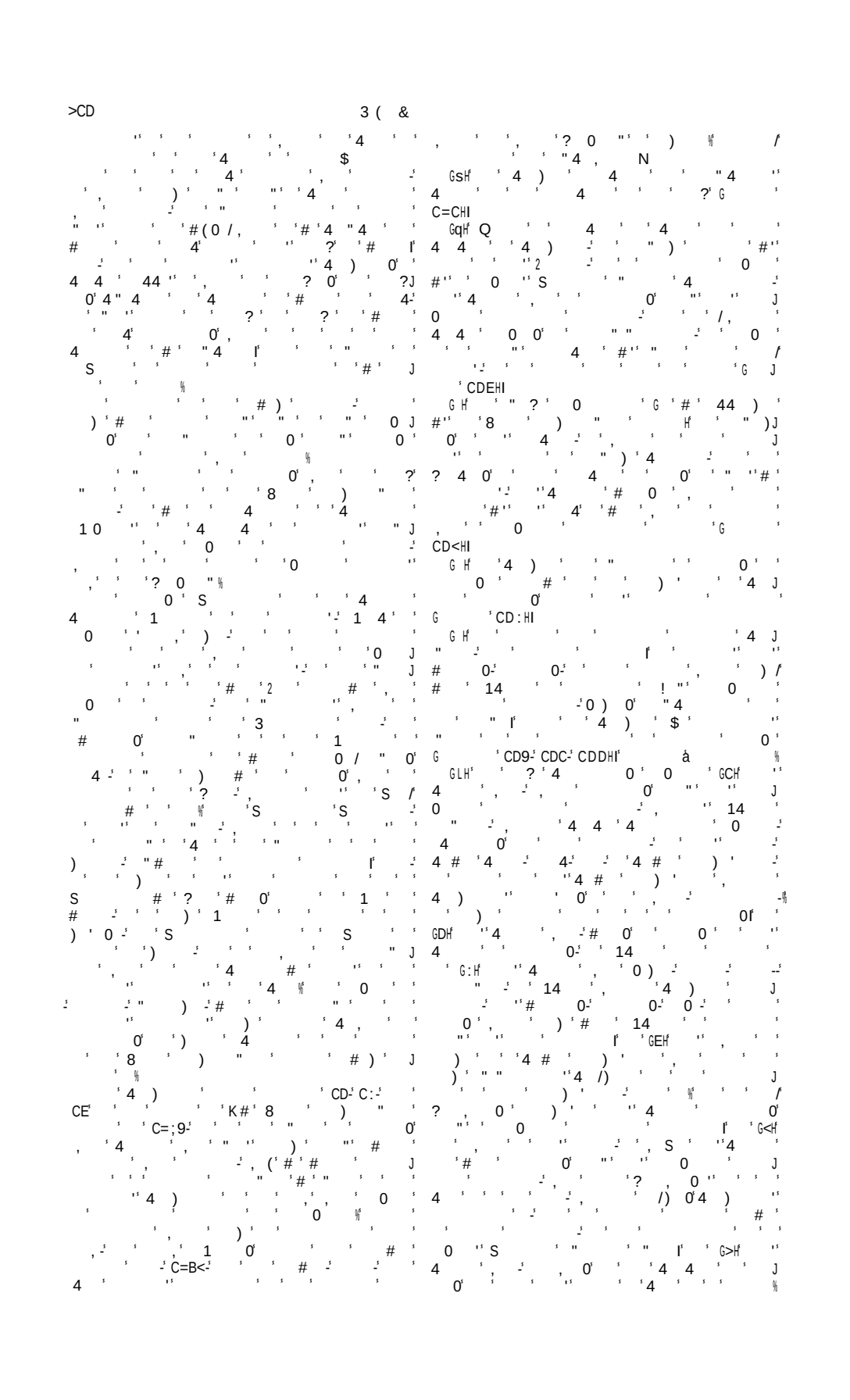

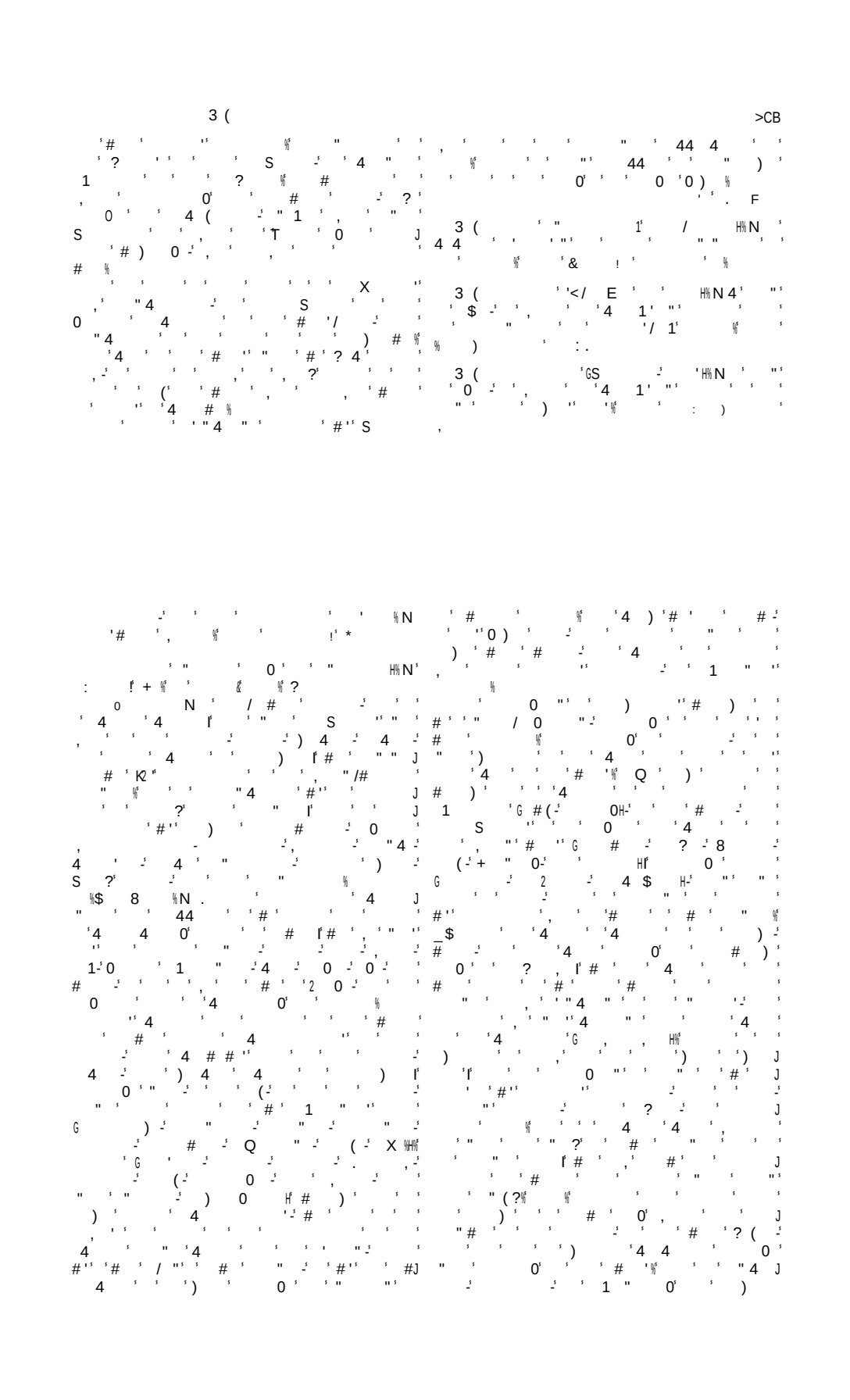

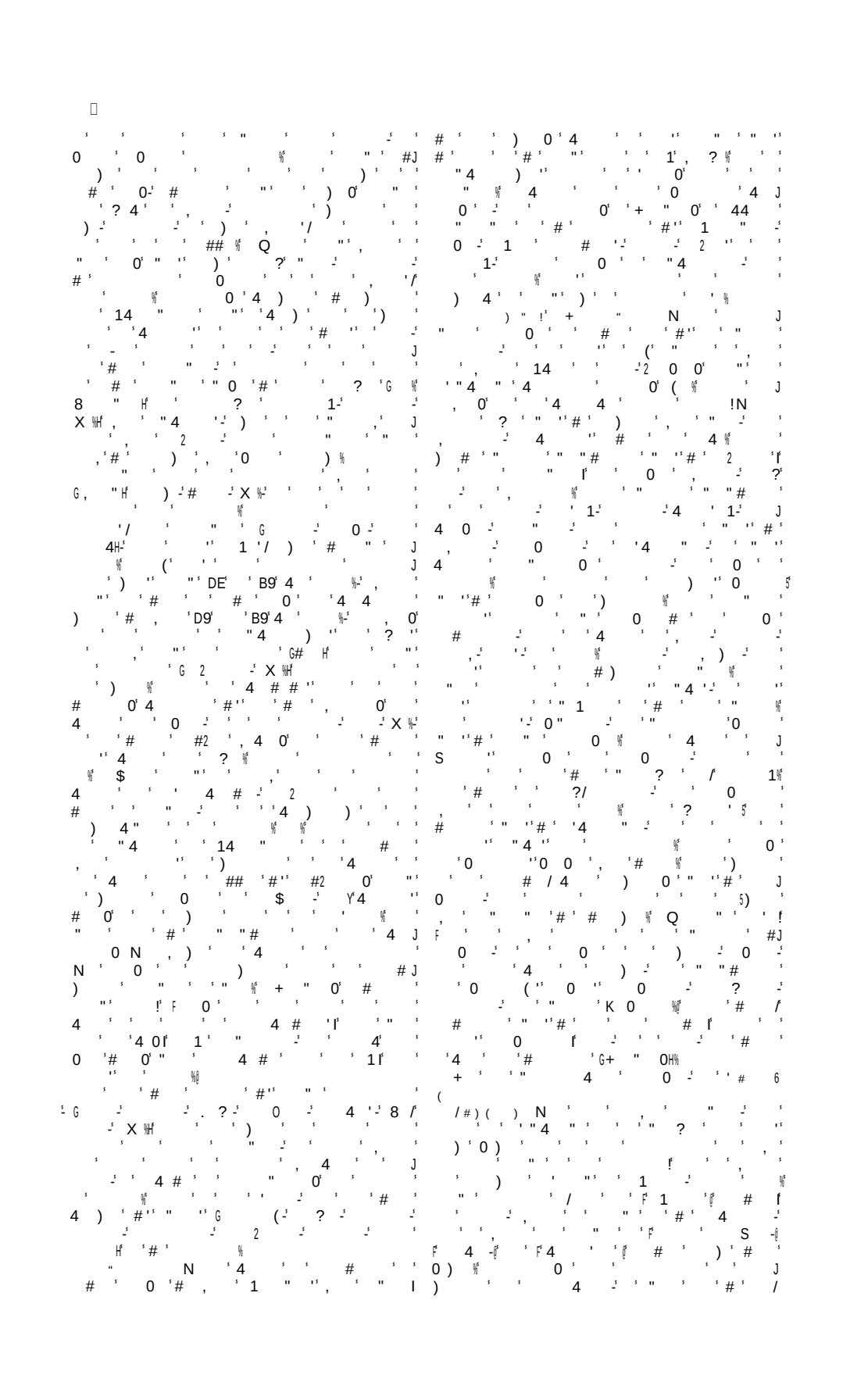

spinal cord. The prognosis of the latter is grave in the extreme.

In the condition of neurasthenia, asthenopia, with difficulty in or real loss of the power of accommodation, may be one of the causes of the impaired vision just mentioned. Physical changes in the retina and optic disc, such as those detailed by Dr. Clifford Allbutt, are extremely uncommon, and the latest writers on this subject, namely, Mr. Page and Mr. Thorburn, seem to doubt their occurrence. In all probability, they only exist as sequelæ of organic lesions of the spinal cord and membranes.

Added to this neurasthenic condition, there is often seen a certain amount of functional disturbance, probably of cerebral (cortical) origin, which may be described as chronic hysteria, under which one includes changes of various kinds in the cutaneous sensibility, spasmodic contractions of limbs, and paralyses; and it is often a most difficult question to decide whether these phenomena are functional or real. Cases such as these are frequently the subject of litigation as regards claims for damages against railway companies.

Medico-legal Questions in Connexion with Railway Accidents. — In cases of claim for compensation for these injuries, it is of the highest importance that the medical men engaged should make themselves thoroughly acquainted with all the circumstances connected with the accident and its results. This applies to the *medical attendant* of the injured person, as well as to the *medical officer* examining on behalf of the company.

Duties of the Medical Attendant.— 1. It is desirable to obtain in writing the *patient's statement* as regards: (*a*) the accident; ascertaining, if possible, the approximate speed of the train when the accident occurred, the position of the injured person in the carriage, and of the carriage in the train; also whether other persons were present or not; (*b*) his condition from the time of the accident to the time of his examination; and (*c*) the symptoms complained of at the time of his examination.

2. Investigate the general condition of the patient, especially as to his appetite, and his capacity for sleep or work; ascertain also his previous habits. The possible existence of organic disease, previous to the accident, should not be overlooked, as it has happened that symptoms referable to disease—tabes dorsalis, for example—have been erroneously ascribed to injury. The urine should be carefully examined in every case.

3. Note bruises or any sign of local injury on any part of the body.

4. Where injury to the spine is alleged, the investigation should be conducted as far as possible according to the following systematic plan:—

(i.) Notice the amount of mobility dity of the spine whilst the patien dressing.

(ii.) Examine the spine by digital p or percussion, and by the applicatio or cold sponges.

(iii.) Investigate any alleged p symptoms by (*a*) measuring the cir ence of the limbs, where needful; th side, it should be remembered, is somewhat fuller than the left, and th ence of any other pre-existing inequ the limbs should not be lost sight of; ing the electrical excitability of the m (*c*) noting the existence of spasm or of the muscles of the spine and limb (*d*) examining the condition of the r superficial and deep.

5. Investigate the presence of any mal cutaneous sensibility. This is e a subjective phenomenon, on which re cannot always be placed.

6. Ophthalmoscopic examination m made, in order to determine the existe not of local lesion in the fundus oculi firmatory or otherwise of cerebral or s symptoms; but, as already stated, pathological changes are exceedingly ra

During this examination, it should be in mind that the simulation of symp such as spinal tenderness or muscular t can frequently be detected by distracti attention, when pressure on the part viously complained of may be made impunity, or the muscular tremors cease. This, however, is not conclusiv imposture, for in hysteria, when the atten is diverted, the same occurs.

As an instance where the truth of a pati statements may be tested by the astute of the medical man, a case may be mentio in which the plaintiff, who had travelled some fifty miles to London to be exami stated, among other symptoms, that his u continually dribbled from him. The surg immediately asked to see his shirt, which been worn at least six hours, when it found perfectly dry and devoid of any st of urine! In another case a man present extreme spinal tenderness, even to the ext of complaining of pain when the part w blown upon with the breath. A sheet paper being interposed, without the patien knowledge, the effect was the same.

It now becomes the duty of the medic attendant to form an opinion on the followi points:—

(*a*) Has the patient been really injured?

(*β*) What is the nature of the injury?

(*γ*) Is the injury a possible or probabl result of the accident as described?

(*δ*) Are the symptoms consistent with history and the objective signs?

Duties of the Medical Office amining on behalf of the Ra Company. — The medical officer

y should on no account constitute the agent of the company for settling ms of compensation. The examina- ould be made, if possible, in the e of the medical attendant of the , and not in the presence of the legal s of either side; it should be con- with thoroughness and tact, and t inflicting any unnecessary mental ly pain.

ort of the case should be drawn up ime, giving:—

The patient's account of the accident, f his subsequent and present symp-

The present condition of the patient, particularly any objective signs of .

An opinion as to whether the symptoms ained of are likely to be the result of cident; and as to the probability of re- y, and at what period.

the plaintiff's solicitors in an action pply for a copy of this report, it should, urse, be worded with extreme care.

e actual question of pecuniary com- ation does not concern either the medical ndant of the patient, or the medical ad- of the company. They merely have tively to bring forward facts in support ir opinions as to the value of symptoms, how far they are dependent upon the y.

ich investigation should take place as after the accident as possible, by which ns the chances of imposture would be ened; whilst by a careful and impartial nate of the facts of the case as obtained such a thorough examination as that ched above, much conflict of medical nion would be avoided, the medical men g witnesses, not advocates.

Fraudulent Claims.—It will be well to ide to some of the ways in which fraudu- t claims are brought against railway com- ies. These may be conveniently divided o:—

(1) Claims made by persons who, as may subsequently proved, were not even present the time of the accident;

(2) Claims by those who, though present nd unhurt, yet simulate the symptoms of jury; and

(3) Claims by those who, having sustained me trifling injury, wilfully and intention- ly exaggerate their symptoms in order to tain a larger amount in compensation.

The medical man should, therefore, be live to the possibility of wilful deception being practised on him, lest he should be d away by a well-planned history, and thus ittingly be made a party to such nlent transactions.

Unintentional Exaggeration.—The ty of assessing the value of subjective ms in general is much increased by the fact that there are certain persons who, undoubtedly injured, may, without any fraudulent design, unintentionally exaggerate their symptoms. This is to some extent explained by their thoughts being constantly directed to their sufferings, and the worry necessarily attending a protracted lawsuit, or whilst an action for damages is pending. The suspense and anxiety, the examinations by the medical men, and the repeated interviews with their solicitors, keep them in a constant state of nervous tension. When, therefore, their claims are settled, it is natural that the relief they experience should frequently be attended by beneficial results, or even complete recovery. *See* FEIGNED DISEASES.

TREATMENT.—The chief injuries received at the time of a railway accident being surgical, the treatment adapted for each particular case will be found in surgical works. Nevertheless there are some general points in the immediate treatment to which any medical man present on such occasions would do well to attend.

1. *Hæmorrhage.*—Death from hæmorrhage should be prevented, where possible, by promptly adopting pressure of some kind. If no tourniquet or indiarubber band be available, a handkerchief tied round the limb and twisted tight with a piece of stick, or direct pressure by the finger, will suffice for the time.

2. *Fractures.*—Temporary splints may be improvised out of umbrellas, walking-sticks, cushions, newspapers, and broken pieces of wood, &c., fixed by straps or handkerchiefs, so that the injured may be removed with as little pain as possible, and simple fractures may be prevented from becoming compound. Simple dislocations should be reduced at once, if possible.

3. *Shock, collapse, and fright.*—In the treatment of these conditions great caution is required to maintain the vital powers until reaction sets in. The temperature of the body, the strength and rate of the heart's action, together with the respiration, should be kept up by stimulants and warmth. Sir William Savory, in his article on 'Shock' in Holmes's *System of Surgery*, is careful to point out the dangers of *over*-stimulation, whereby the flickering powers of nature may be extinguished altogether.

4. *Exposure to wet and cold.*—Every endeavour should of course be made to prevent prolonged exposure, by sheltering the injured as much as possible, and securing their early removal to any neighbouring houses.

The subsequent treatment of railway injuries is one which requires the exercise of considerable skill and judgment on the part of the medical attendant. Absolute rest is of course a *sine quâ non* where any spinal concussion or local lesion is suspected; but

where the symptoms are due to neurasthenia, long confinement in the horizontal position is often productive of harm, whereas change of scene and moderate exercise might prove beneficial.

WILLIAM ROSE.

RÂLES (Fr., Rattles).—Certain adventitious sounds heard on auscultation, in connexion with the respiratory organs, during the act of breathing, in various morbid conditions. *See* PHYSICAL EXAMINATION; and RHONCHUS.

RAMOLLISSEMENT (Fr., Softening).—This word is associated with all forms of softening of tissues and organs; but by English pathologists it is generally used in connexion with softening of the central nervous system. *See* SOFTENING.

RANULA (*ranula*, dim. of *rana*, a frog). A cystic growth in the floor of the mouth. *See* MOUTH, Diseases of.

RAPE.—SYNON.: Fr. *Viol*; Ger. *Nothzucht*.

DEFINITION.—By the English law rape is defined as 'the carnal knowledge of a woman forcibly and against her will.'

GENERAL REMARKS.—The crime of rape is punishable by penal servitude for life. By the Criminal Law Amendment Act of 1885 the defilement of a girl under thirteen is a felony punishable by penal servitude for life, and the attempt to have carnal knowledge of a girl under thirteen is a misdemeanour punishable by two years' hard labour, or by a whipping if the offender be under sixteen. The carnal knowledge of a girl between thirteen and sixteen, or the carnal knowledge of an idiot or imbecile girl, is a misdemeanour punishable by two years' hard labour.

Of cases of rape recorded by Casper, 73 per cent. were upon the persons of little children under twelve. Of 136 cases put upon record by this author, the ages were as follows:—

From	2½	to	12	years of age,	99	cases
„	12	„	14	„ „	20	„
„	15	„	18	„ „	8	„
„	19	„	25	„ „	7	„
			47	„ „	1	„
			68	„ „	1	„

For proof of the crime of rape it is not necessary that the force employed should have been of a violent physical kind. A mere *threat* of violence, or even of moral injury, is 'force' in the eyes of the law. The surreptitious administration of chloroform, or a narcotic, for the purpose of having intercourse with a woman against her will, is also force in the eyes of the law. The Criminal Law Amendment Act quoted above has the following clause: 'Whereas doubts have been entertained whether a man who induces a married woman to permit him to have connexion with her by personating her husband is or is not guilty of rape, it is hereby enacted and declared that every such offender shall be deemed to be guilty of rape.'

The moral character of the woman is theoretically, but seldom practically, beside the question; and, provided force be used, and the woman's consent be wanting, sexual intercourse even with a prostitute is legally 'rape.'

The punishment of the crime of rape was provided for in the criminal code of Moses, who ordained that the ravisher of a betrothed damsel should die.

The Roman law punished the crime with death and confiscation of goods, but provided the following saving clause:—

Rapta raptoris, aut mortem, aut indotatas nuptias optet.

Upon this, says Percival, there arose what was thought a doubtful case: '*Una nocte quidam duas rapuit; altera mortem optat, altera nuptias.*'

Many accusations of rape are false and trumped up, and are only brought by the woman when she finds that some sexual indiscretion is likely to bring her into trouble, or cannot be concealed by reason of her pregnancy.

This being the case, *stale accusations* should be received with very great caution. The laws of Henry III. provided that the accusation should be made immediately '*dum recens fuerit maleficium.*' By the old Scotch law no delay was allowed in bringing the accusation *ultra unam noctem*, and by the modern Scotch law a delay of three days is alone permitted. By the law of England no limit is placed on the time at which an accusation of rape may be made. An English jury is, however, naturally chary of giving credence to a stale charge of rape. Some few years back a charge of rape was brought against a gentleman of position in one of the home counties by a girl with whom he had had connexion some five months previously. There was no evidence that the girl had offered any resistance, and as the accusation was brought only after pregnancy had become evident, and after ineffectual attempts had been made to extort money from the defendant's relatives, and as the charge was evidently made at the instigation of an uncle who was a superintendent of police, and a cousin [illegible] lawyer, the [illegible] we think, a[illegible] that it shou[illegible] stances, to [illegible] crime.

The law [illegible] of rape is s[illegible] amount of [illegible] touching of [illegible]

knowledge in the eyes of the law. The complete introduction of the penis into the vagina need not be proved, and still more is proof of emission unnecessary.

THE SIGNS OF RAPE.—From what has gone before, it is evident that there need be no signs whatever. If a girl be overawed by a threat and her vulva be touched by the penis, that is rape; and, if proved, is punishable as such.

On the other hand, the evidence of rape may be very convincing; for example:—

(*a*) The woman may have been heard to cry for help.

(*b*) There may be the signs of a struggle at the spot where the rape was alleged to have occurred.

(*c*) There may be damage to the woman's clothing, and bruises of various parts of her body—signs that she has been subjected to physical force.

(*d*) The genital organs may be found injured; the vulva bruised and perhaps bleeding; the hymen recently ruptured; and, in cases where the disparity in size between the man and woman is very great, rupture of the perinæum and mortal injuries to the vagina.

(*e*) Seminal spots may be found upon the woman's clothing, which is a certain proof of a previous 'intimate relation' with a male. Blood-spots also afford valuable evidence, but necessarily not so conclusive. Care must be taken not to confound menstrual fluid with blood.

The concurrence of all these signs would amount to certain evidence of forcible connexion. It must be borne in mind, however, that violence may be done to the female organs in other ways than by forcible connexion, and the medical examiner should be upon his guard against inferring too much from the evidence afforded. He also should be on the look-out for facts which may rebut assertions made by the woman. Thus, signs of a previous pregnancy or the evidence of previous venereal disease (scars in the groin, sores upon the pudenda, or symptoms of constitutional syphilis) may serve to disprove any assertions which might be made as to the woman's virginity or previous chastity. To *prove* whether or no a woman be '*virgo intacta*' is next to impossible, and we can only state the probabilities for and against. Such a question, however, is quite beside the mark in many cases of rape; but the presence of [illegible]tured hymen is an unlikely occur-

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by an unaided man. If a woman be in the enjoyment of her faculties she is capable of offering an amount of resistance which would be well-nigh insuperable; and if she have offered a decent resistance, the person of the ravisher should bear evidence of it.

Rape, as we have seen, is most often committed on children of tender years. It is well to be on one's guard against error with regard to the rape of little children. It must have come within the experience of most members of the profession, and especially of those engaged in hospital practice, to have brought to them children suffering from a purulent discharge from the vagina, the mother at the same time alleging that some one must have violated the child. It must be borne in mind that purulent discharges from the vagina are not uncommon in ill-fed, dirty, scrofulous children; and that after some of the infantile acute specifics, sloughing of the pudenda is a rare, though recognised occurrence. The case of Jane Hampson, æt. 4, who died of sloughing of the genitals at Manchester in 1791, should stand as an incentive to caution in these matters. The signs were considered as those of defloration, and the coroner's jury returned a verdict of *murder* against the boy who slept with her; but luckily for the male child there occurred many other cases of sloughing of the pudenda in Manchester before he was brought to trial, and as the doctor who was called to Hampson recognised and acknowledged his error, the boy was discharged. It was at one time a popular belief that connexion with a virgin was a sure cure for venereal disease, and this has led, no doubt, to many cases of rape on young children. The presence of venereal disease in one or both of the parties may be of value as evidence. Its presence in the woman and not in the man affords a strong presumption against rape.

The finding of spermatozoa within the vagina is proof positive of connexion. But here, again, care must be taken not to mistake for spermatozoa the *trichomonas vaginalis*—a microscopic organism, not unlike a tadpole in shape, which has been described by M. Donné, as occasionally found in vaginal mucus. It must be remembered, also, that seminal fluid may contain no spermatozoa. Rape is occasionally effected with so much violence that death results. Ogston records the case of one Margaret Paterson, who was raped between Edinburgh and Dalkeith by two carters, who took her into their cart on the pretence of helping her on her journey. They forcibly held her down and repeatedly violated her person, and afterwards took stones from the road, coals, straw, prickly plants, &c., and forced them into the vagina. They then left her in a ditch, and she died in three days of her injuries. *Post mortem* the vagina and rectum were found lacerated and broken down into one passage,

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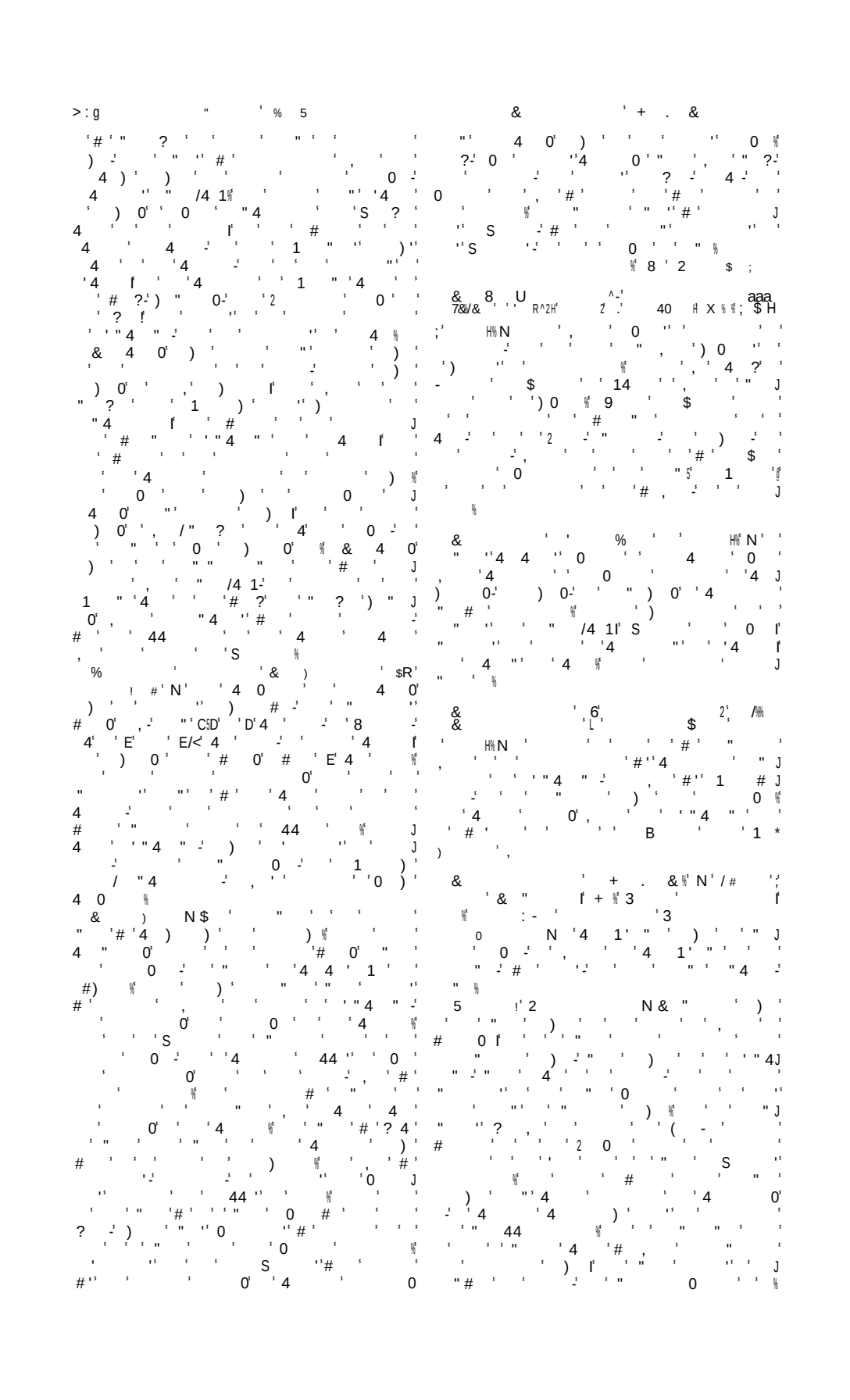

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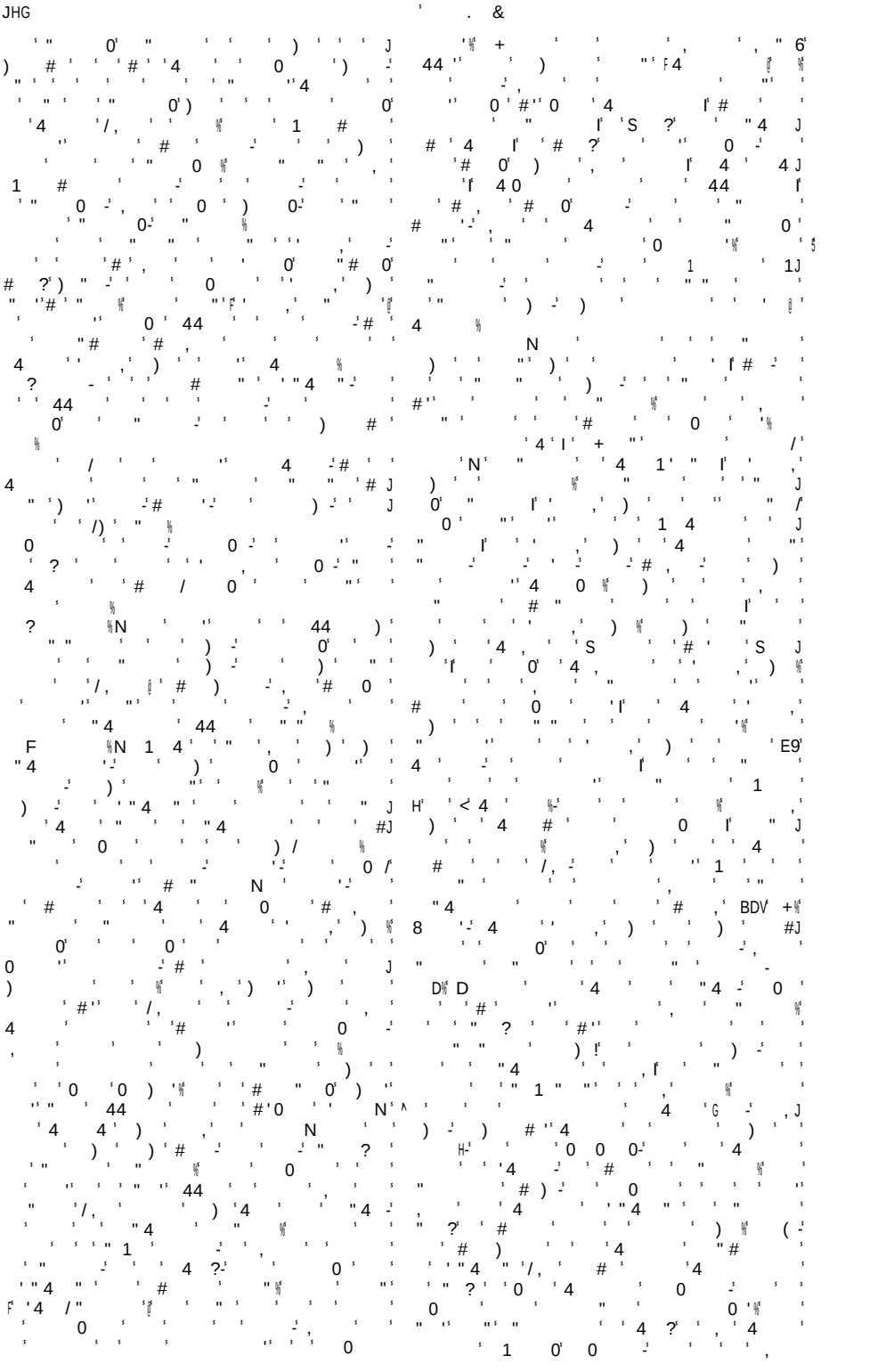

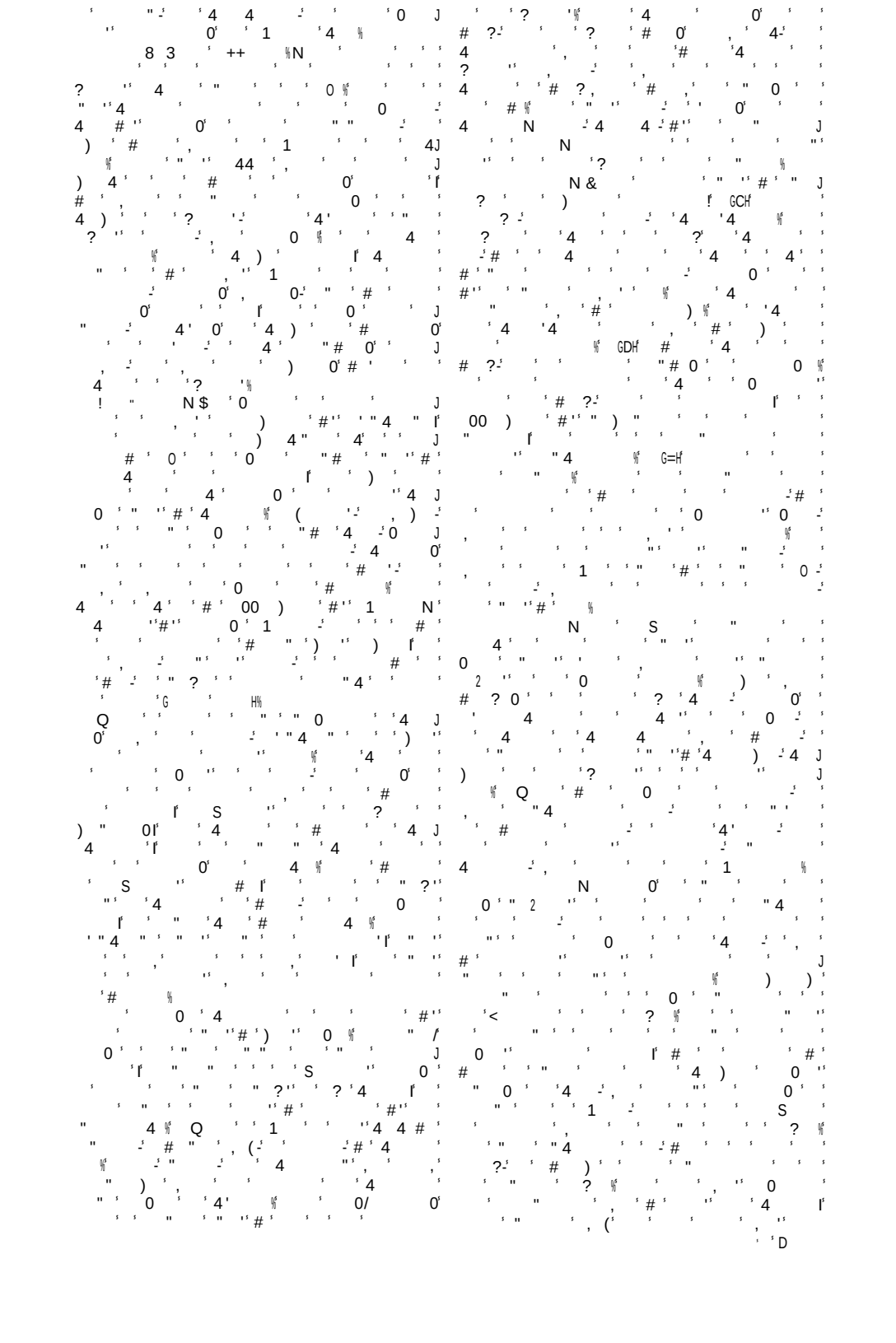

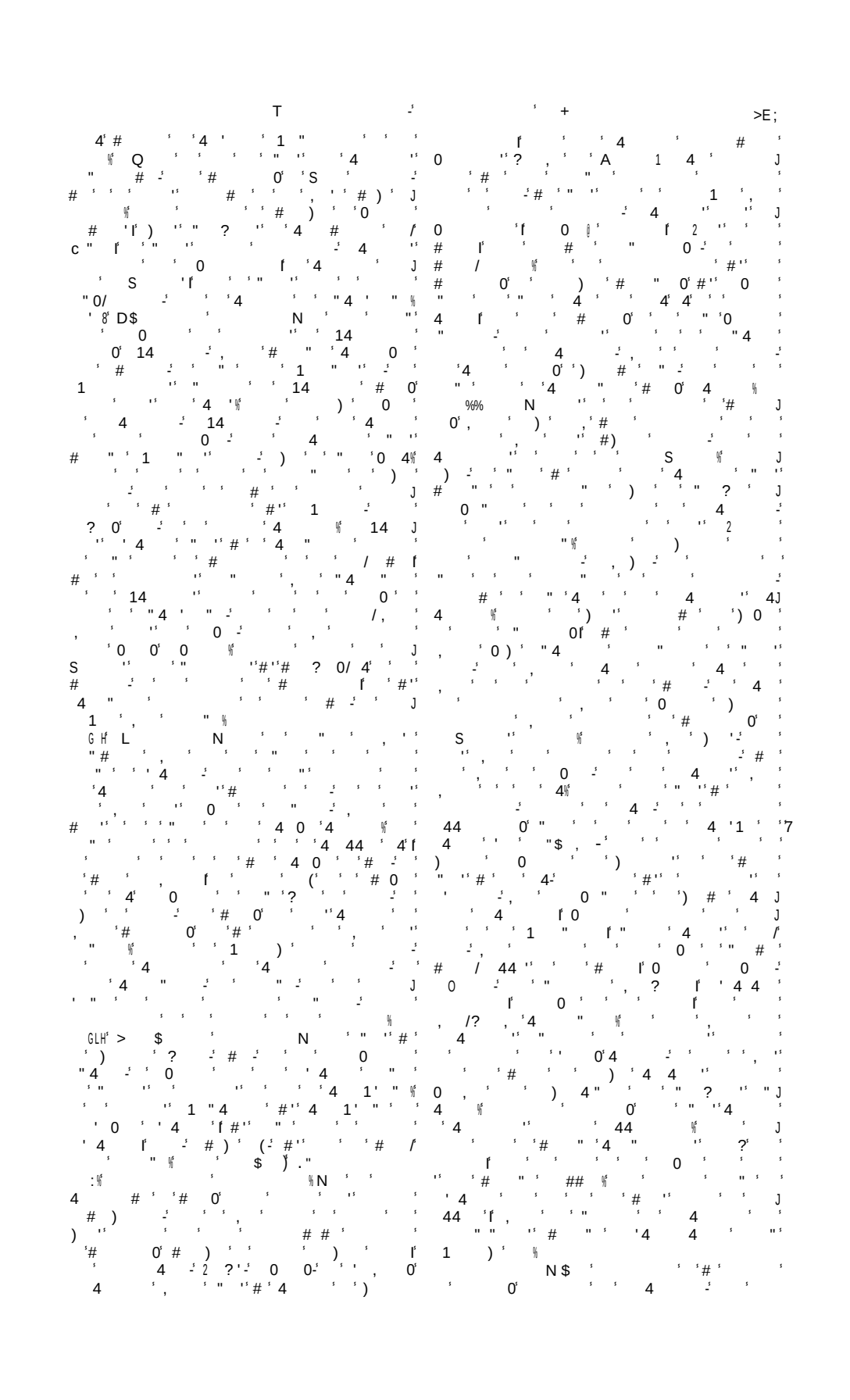

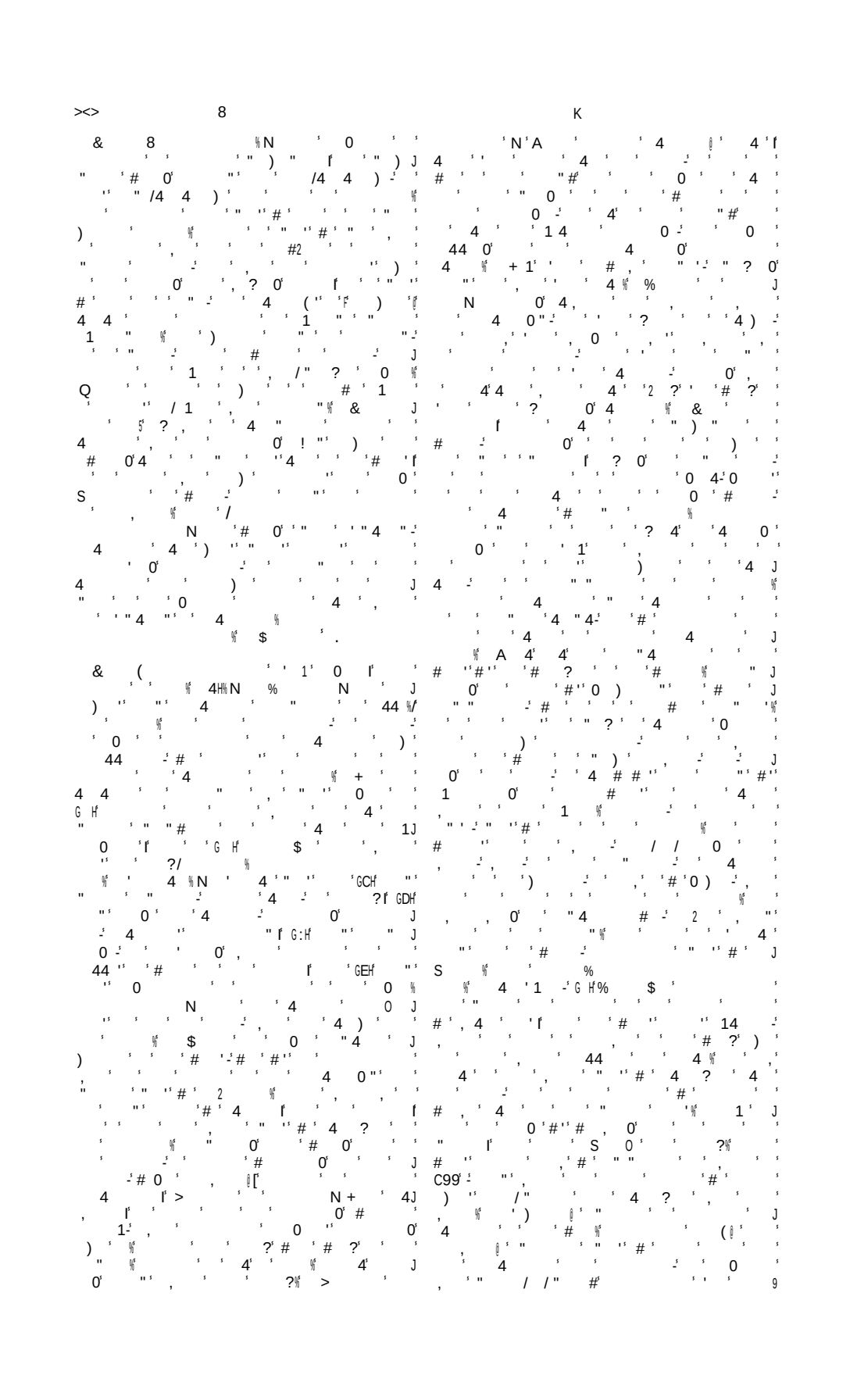

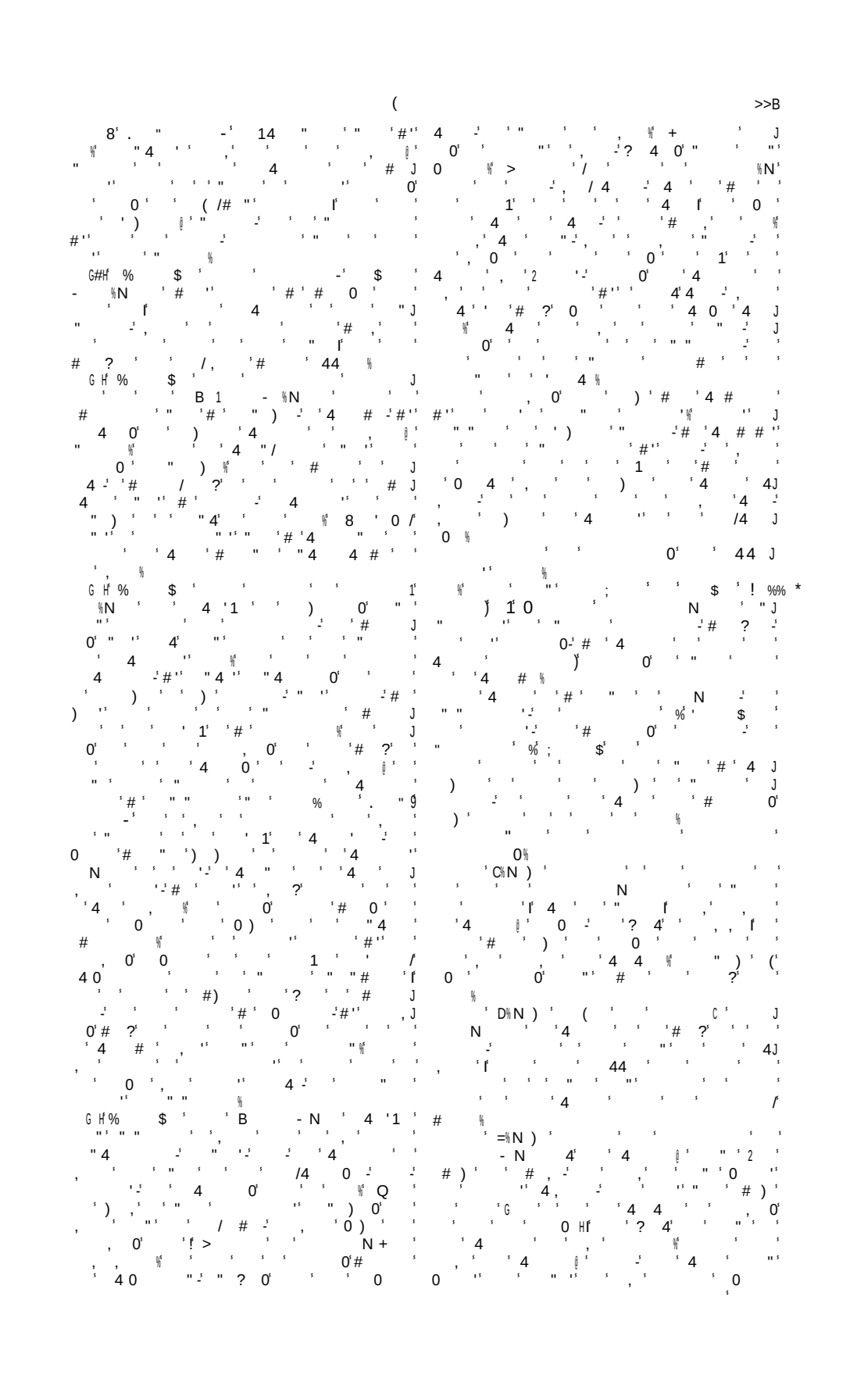

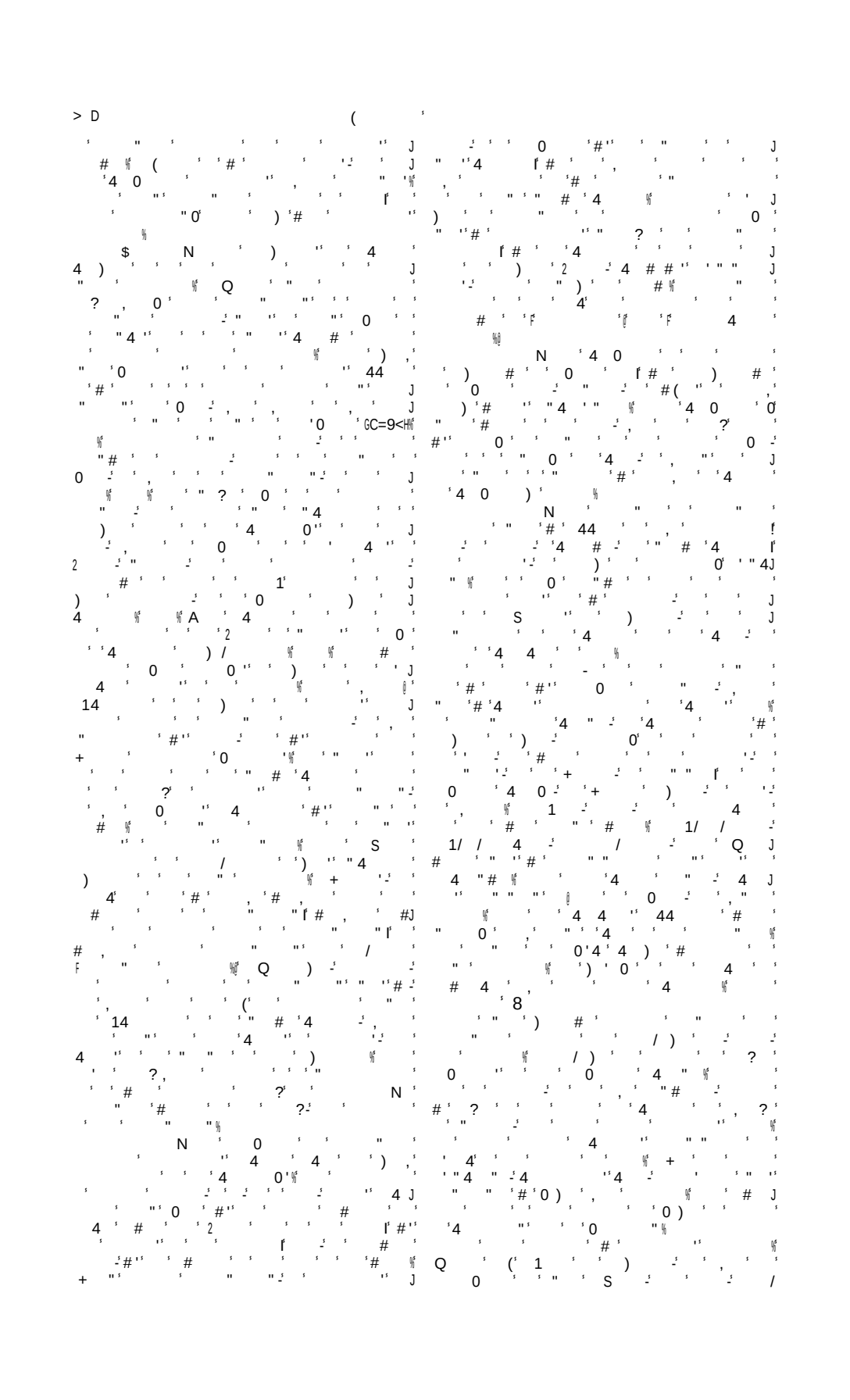

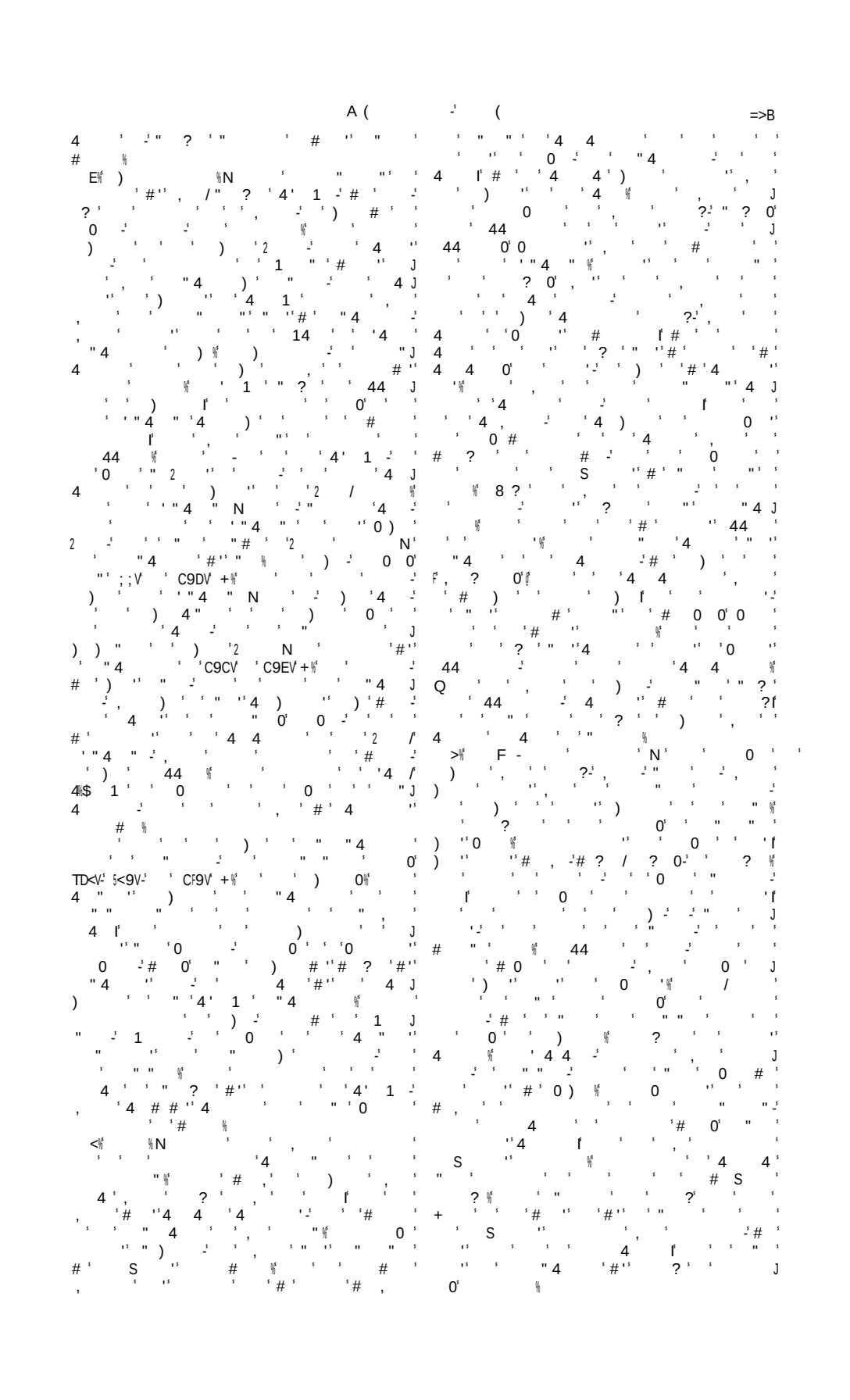

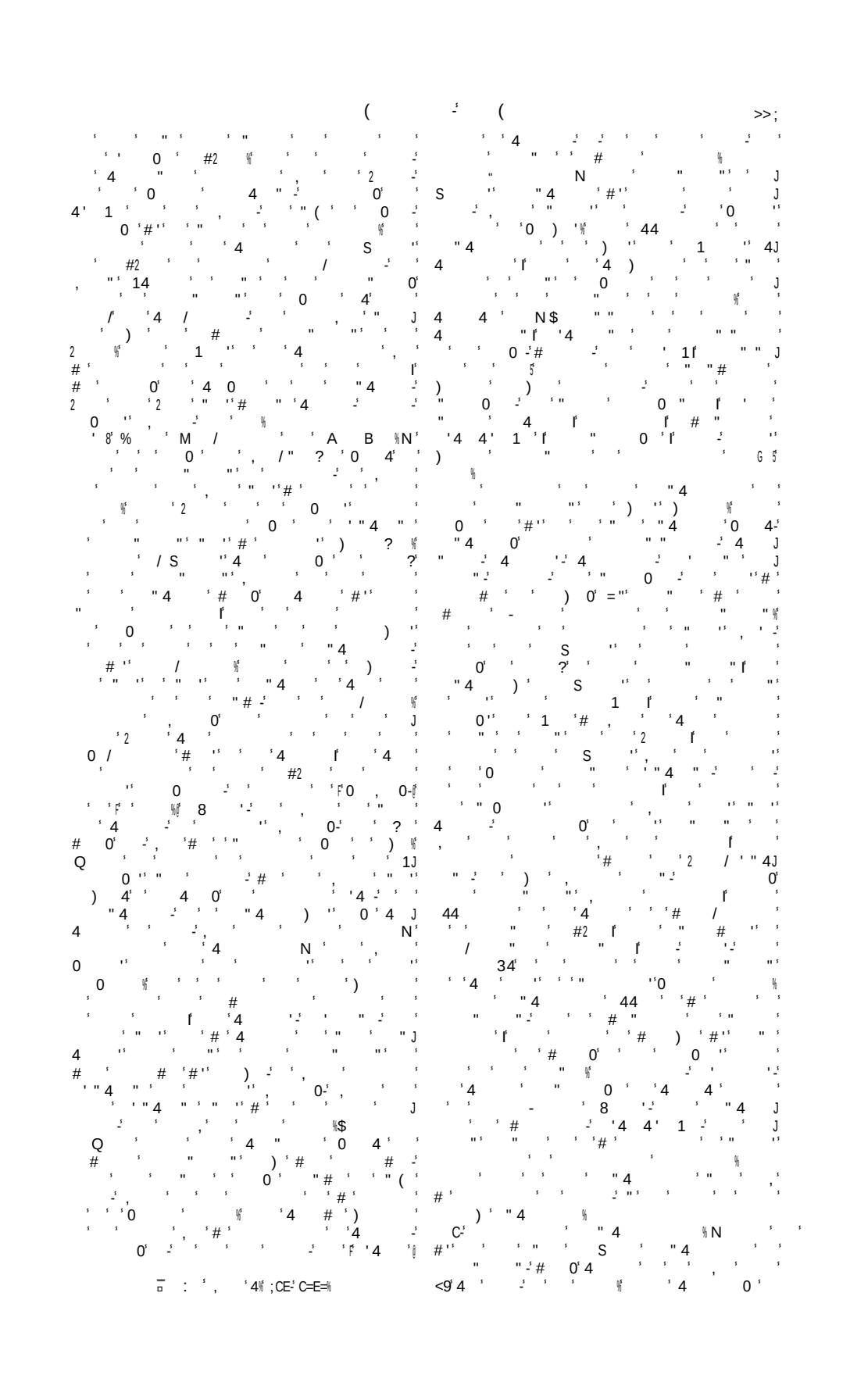

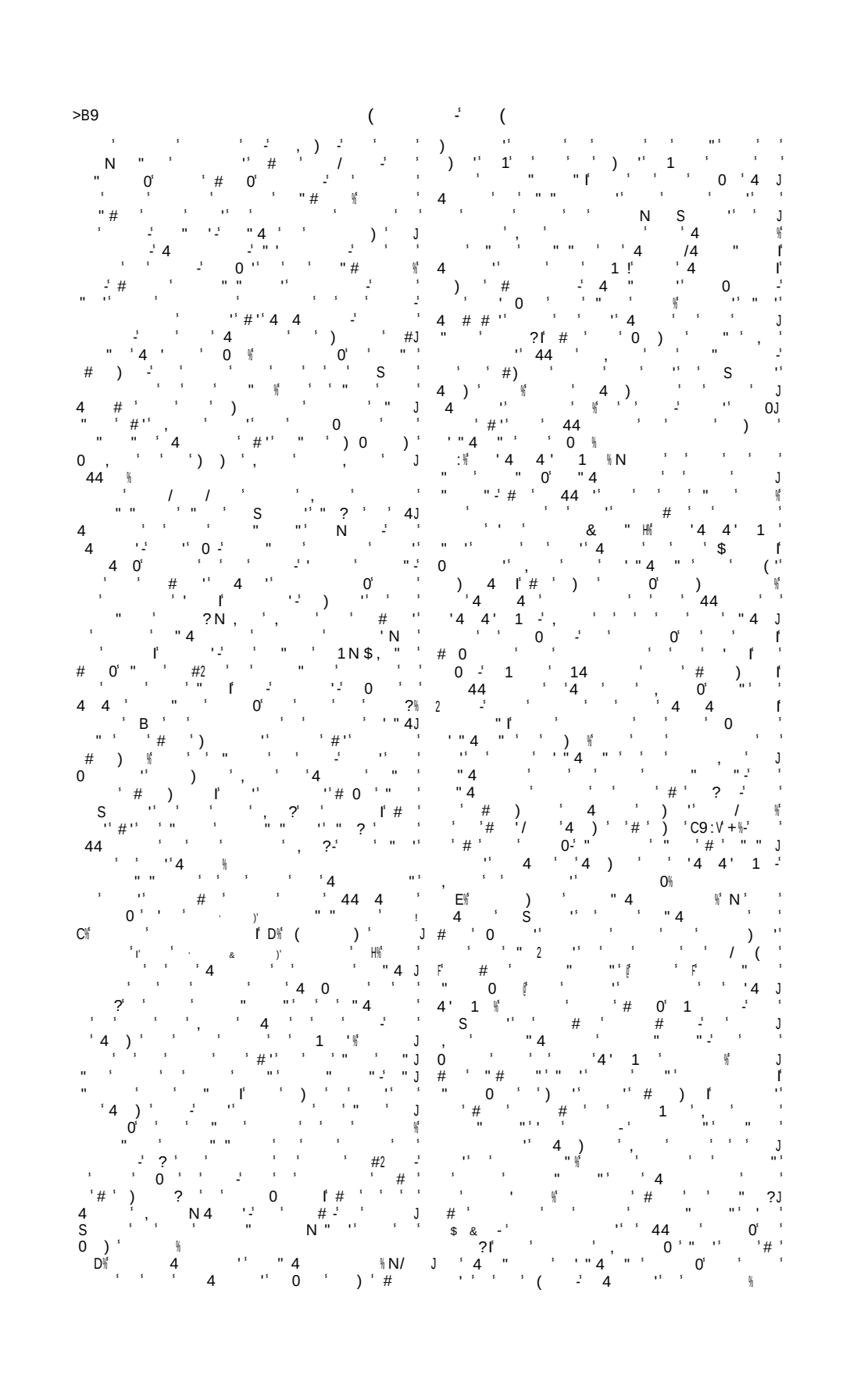

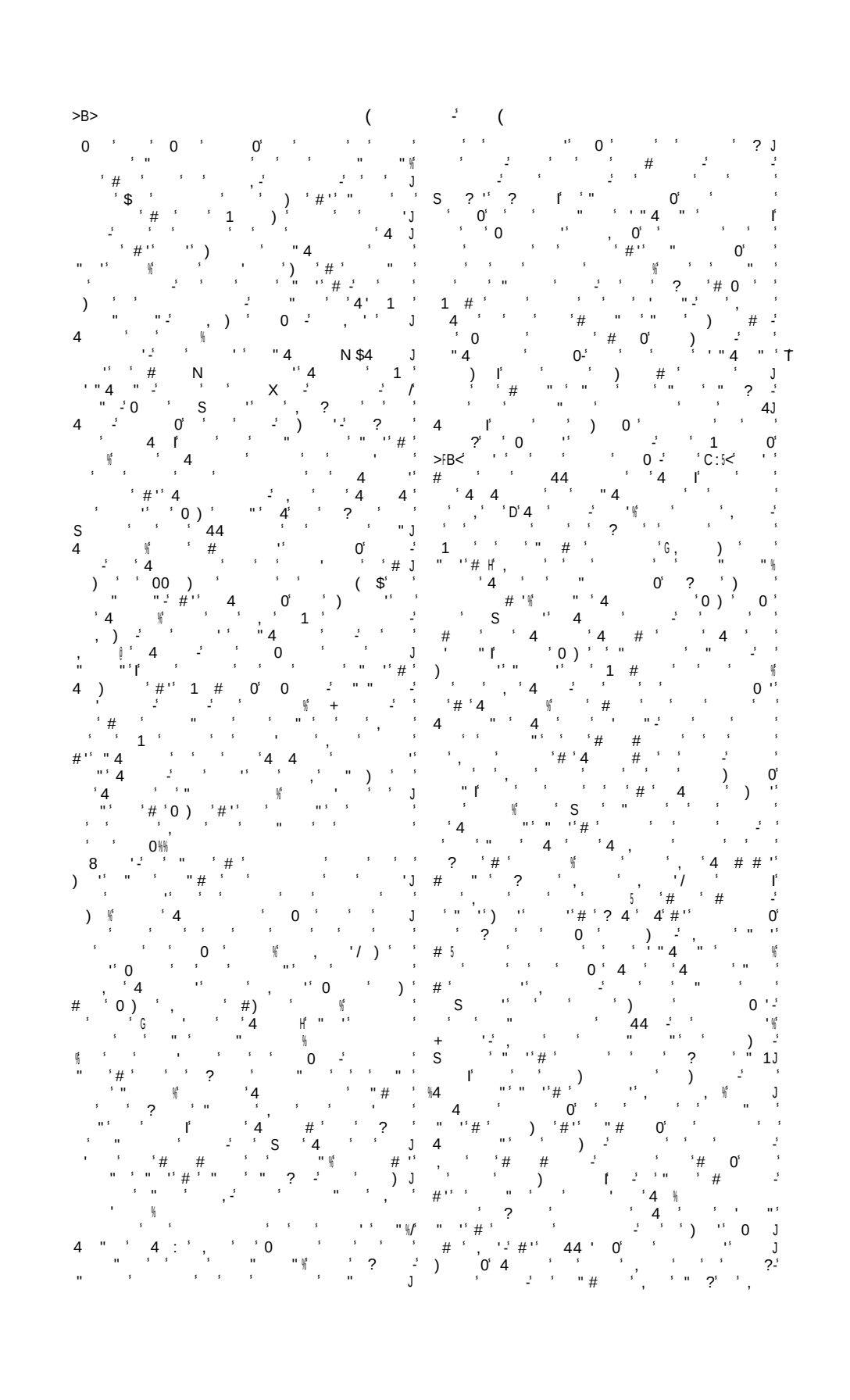

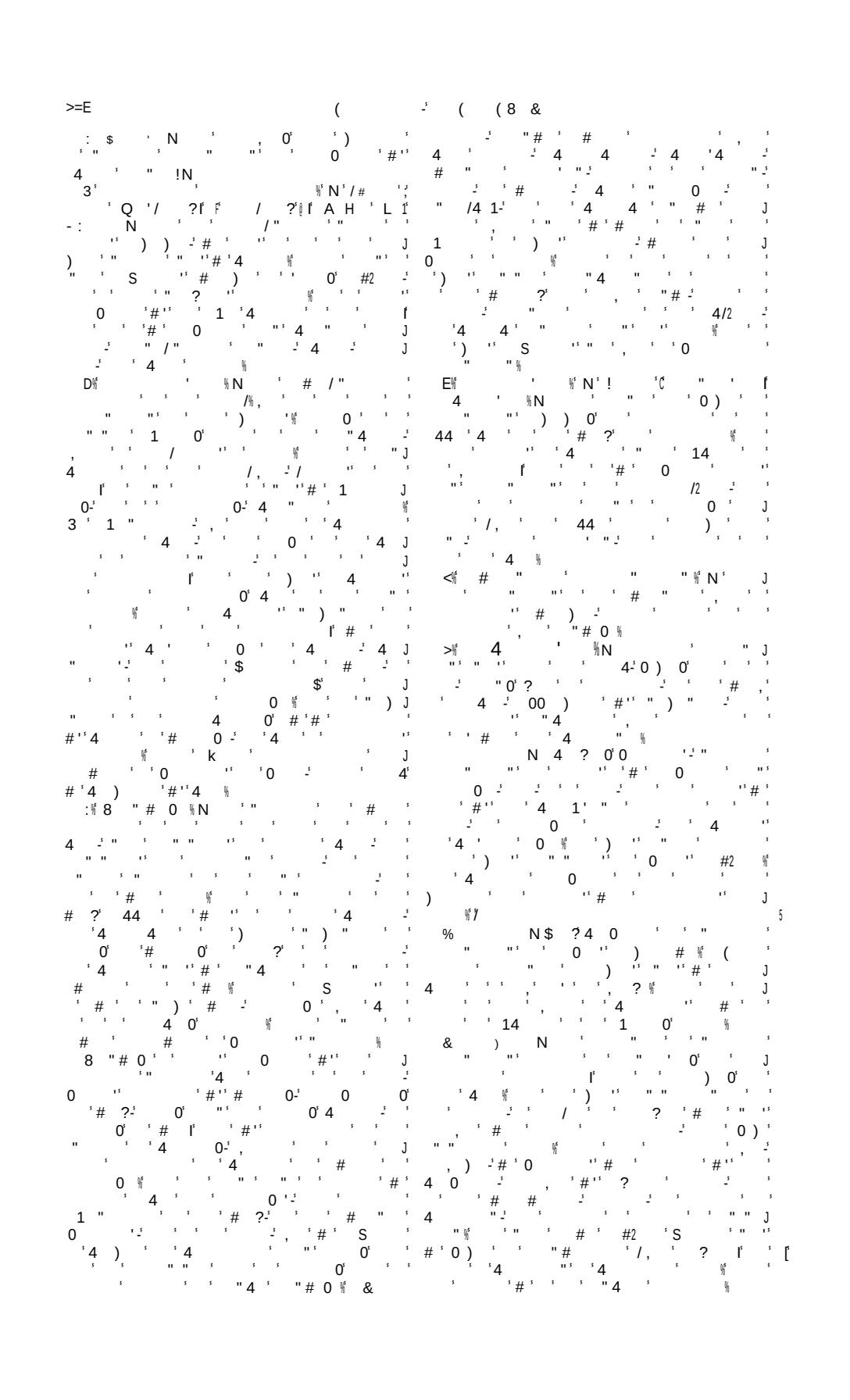

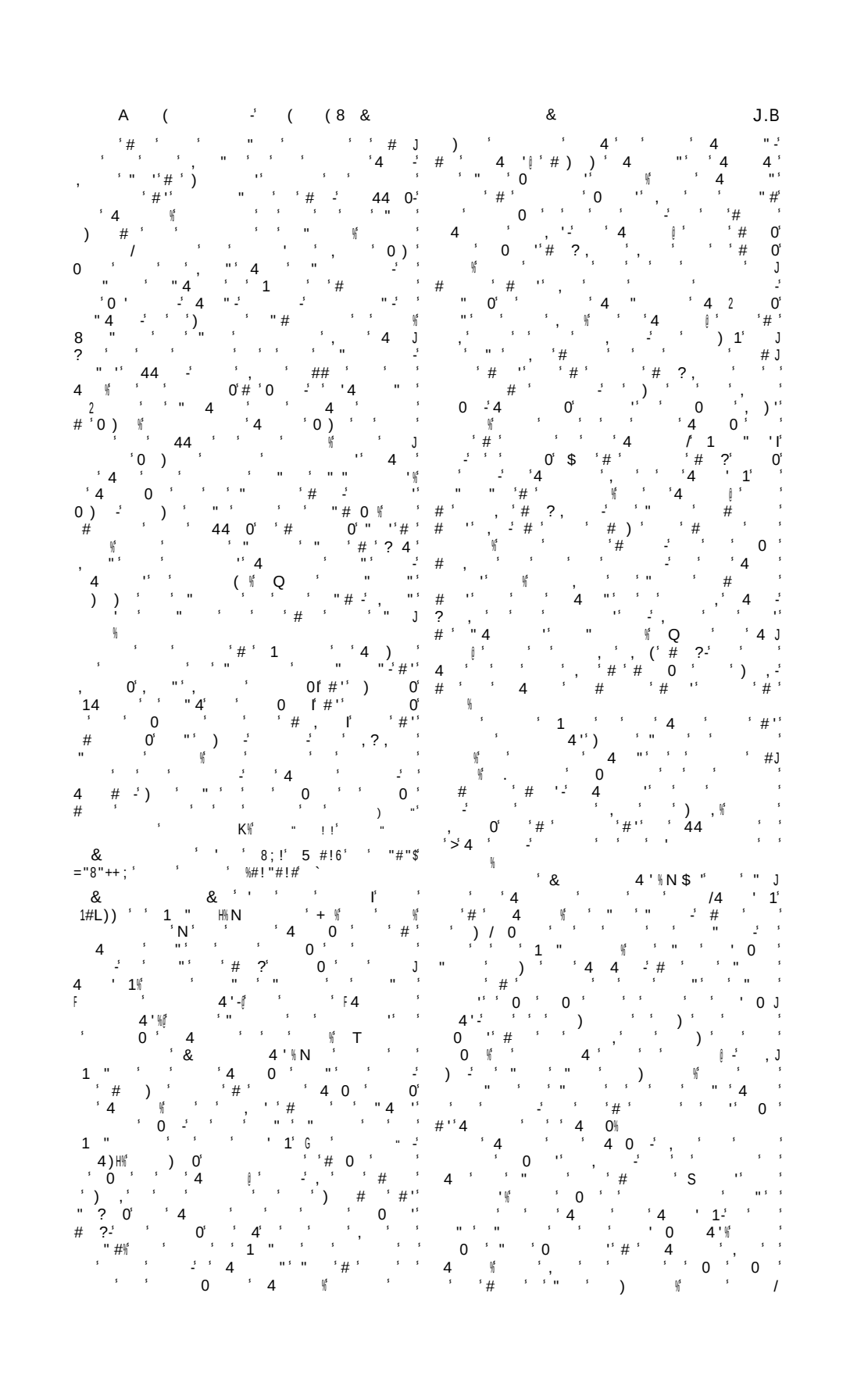

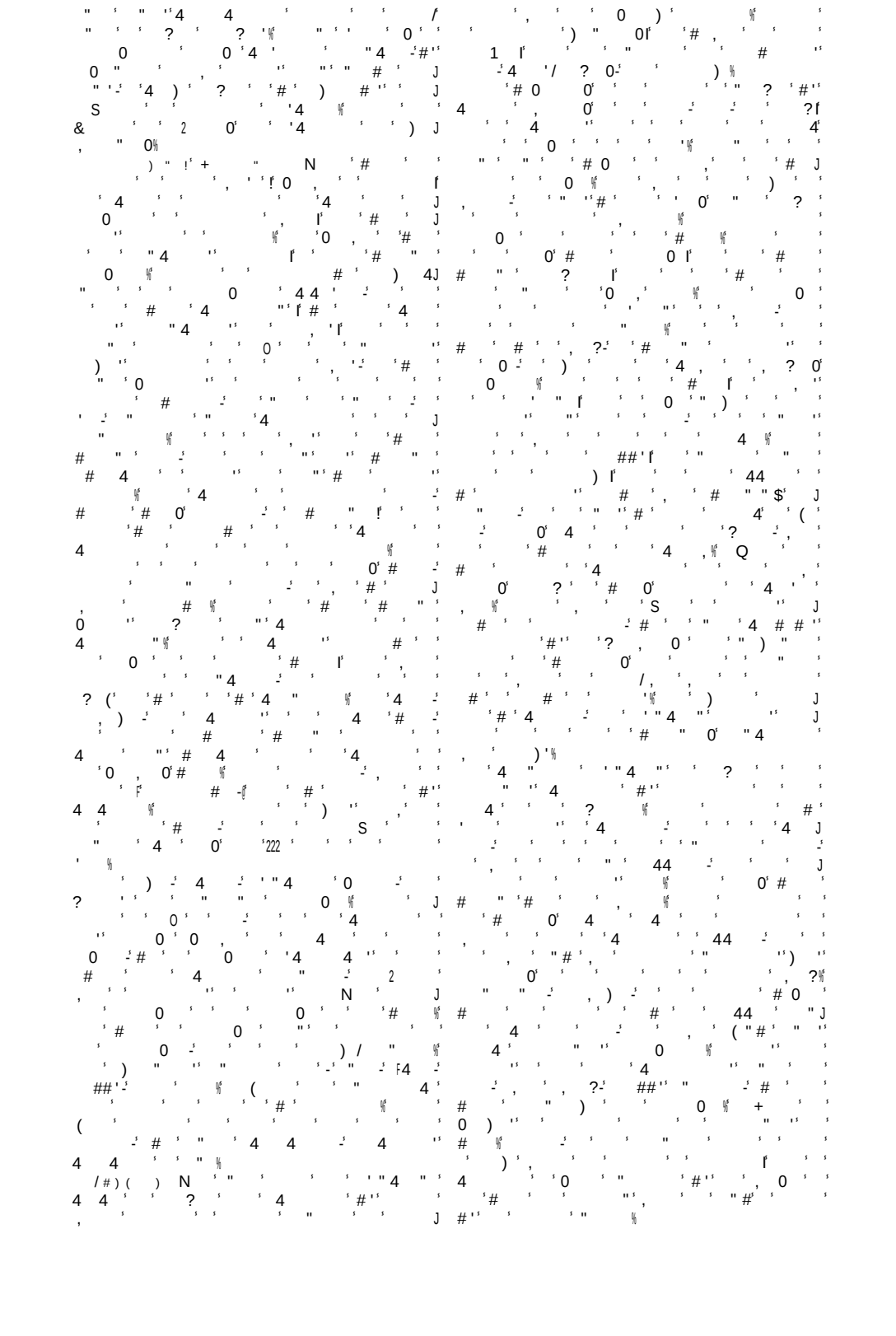

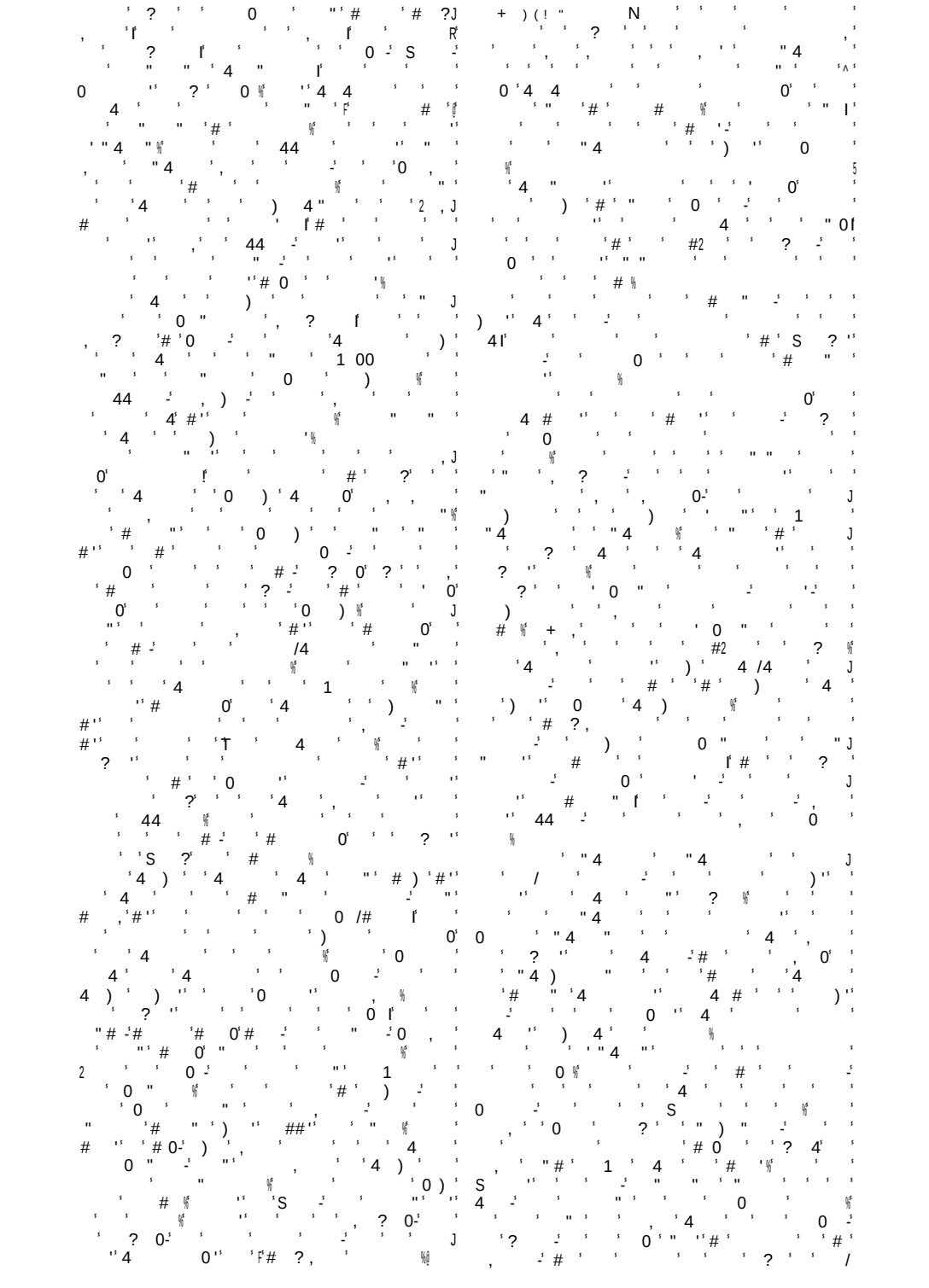

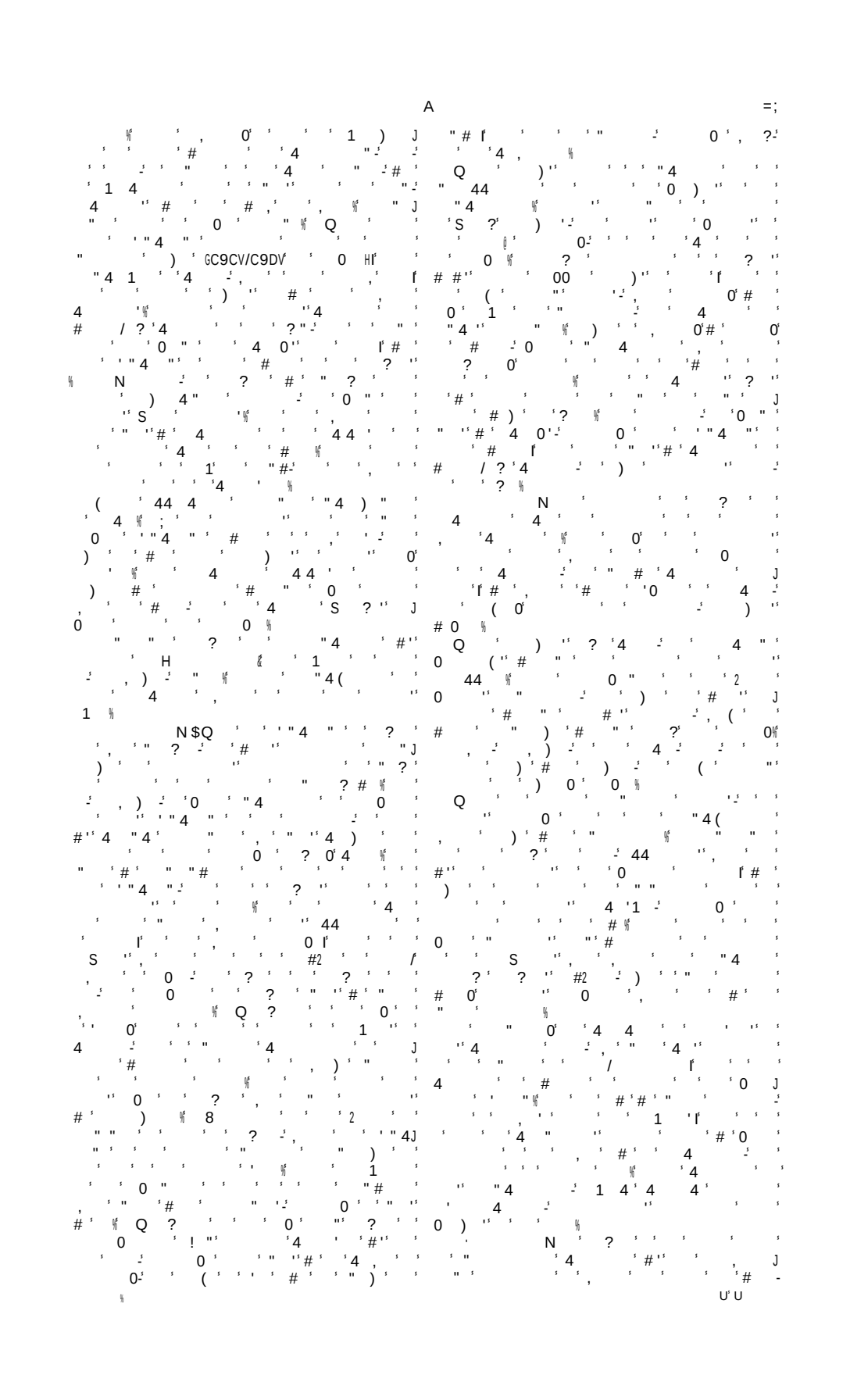

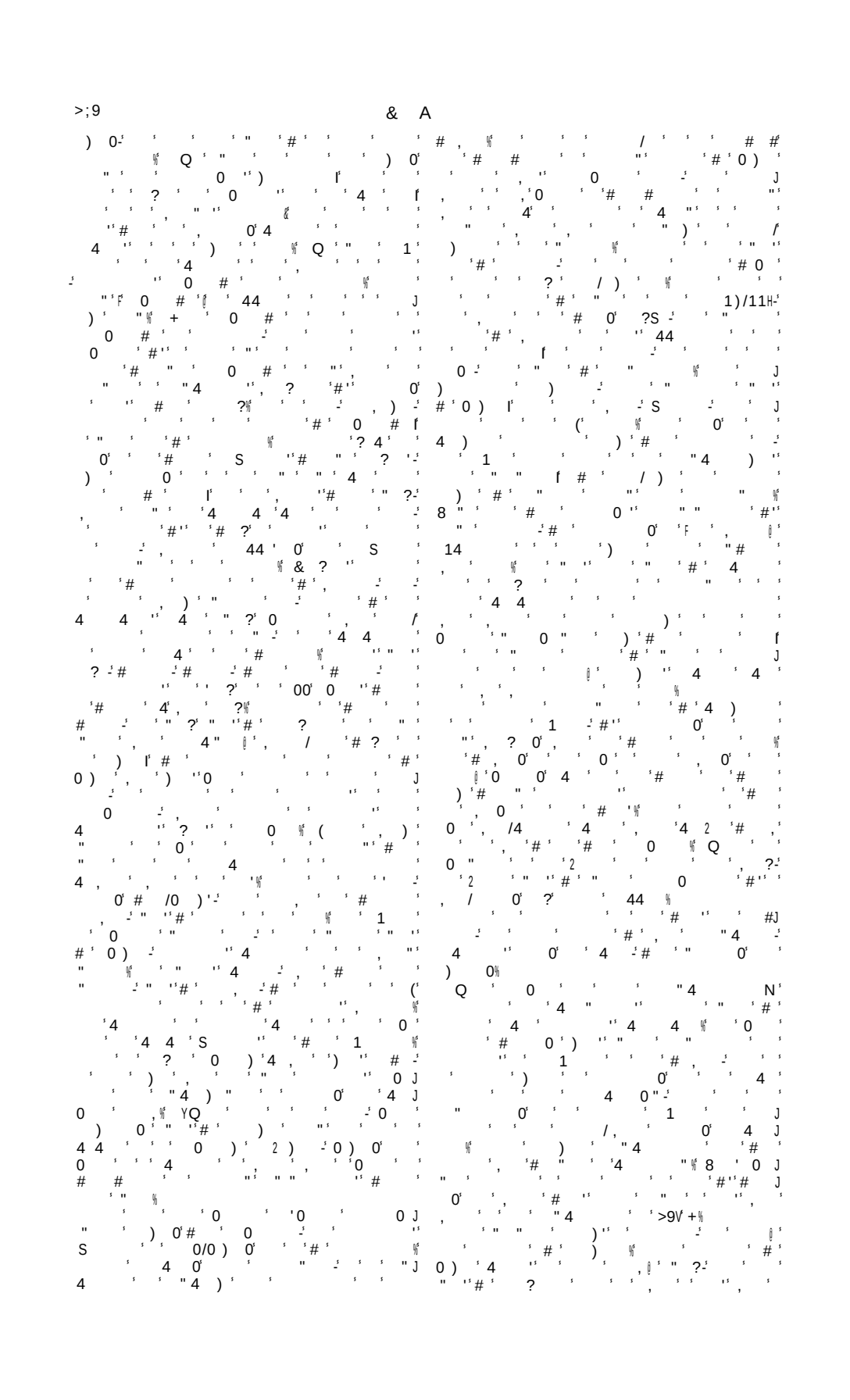

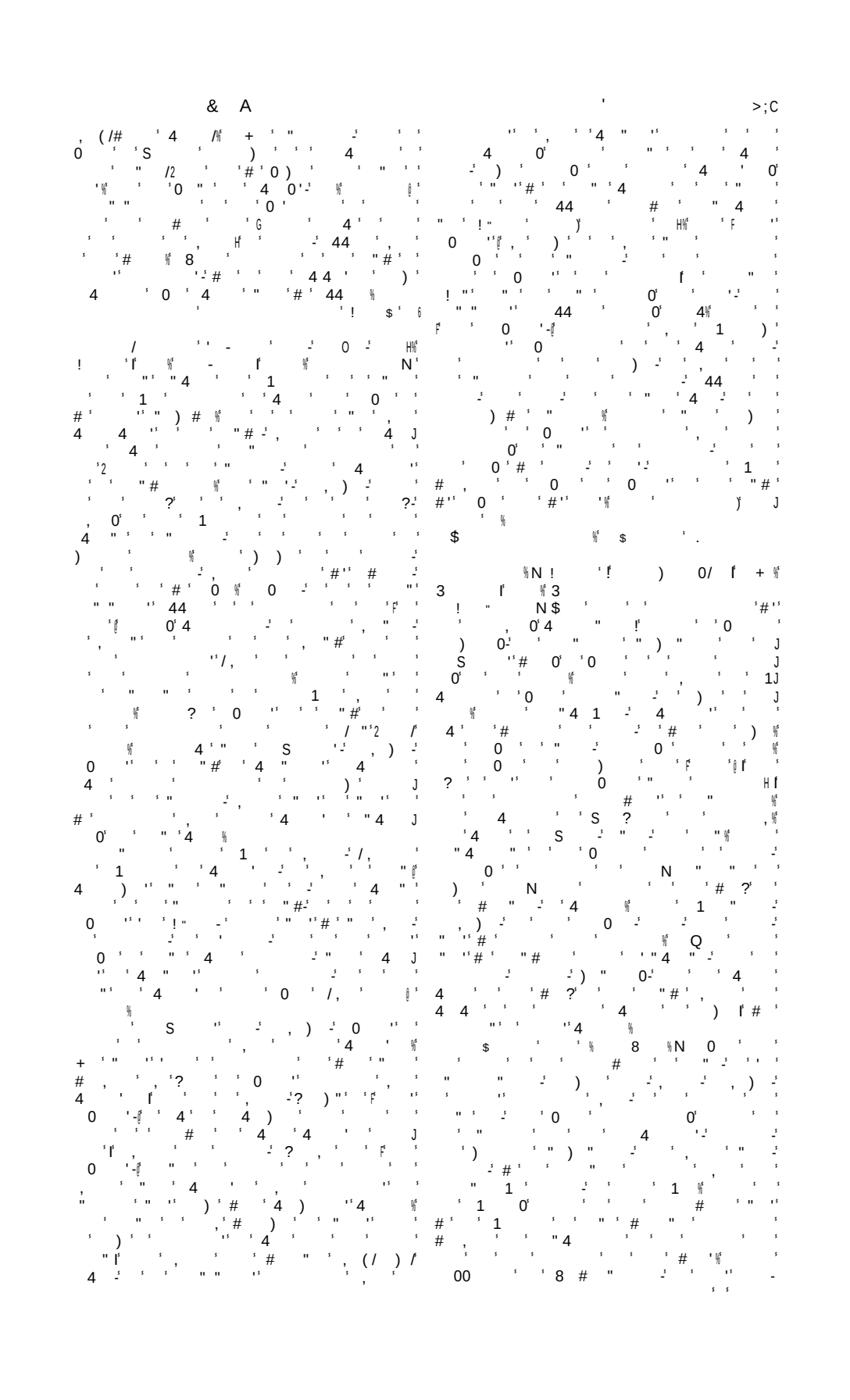

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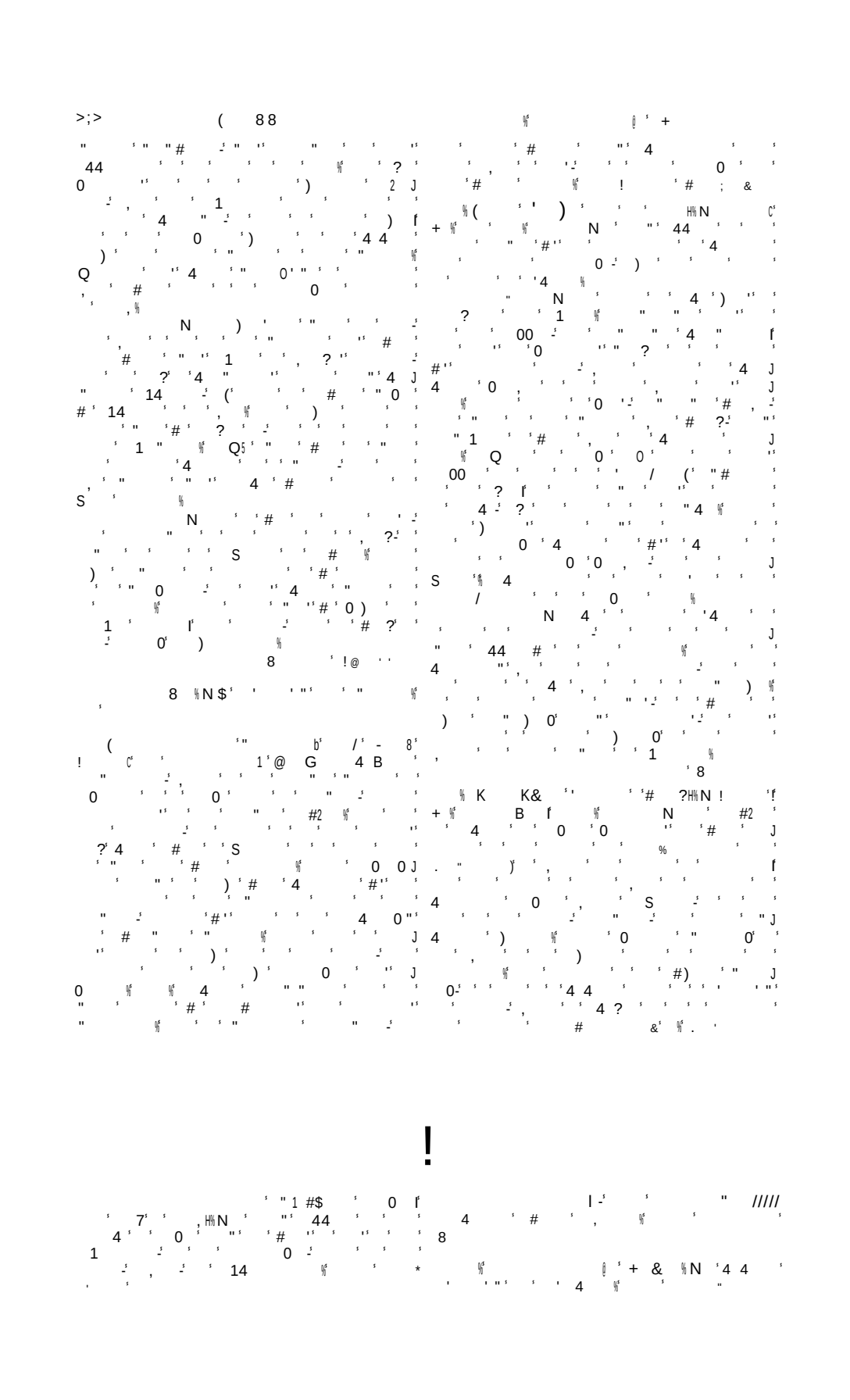

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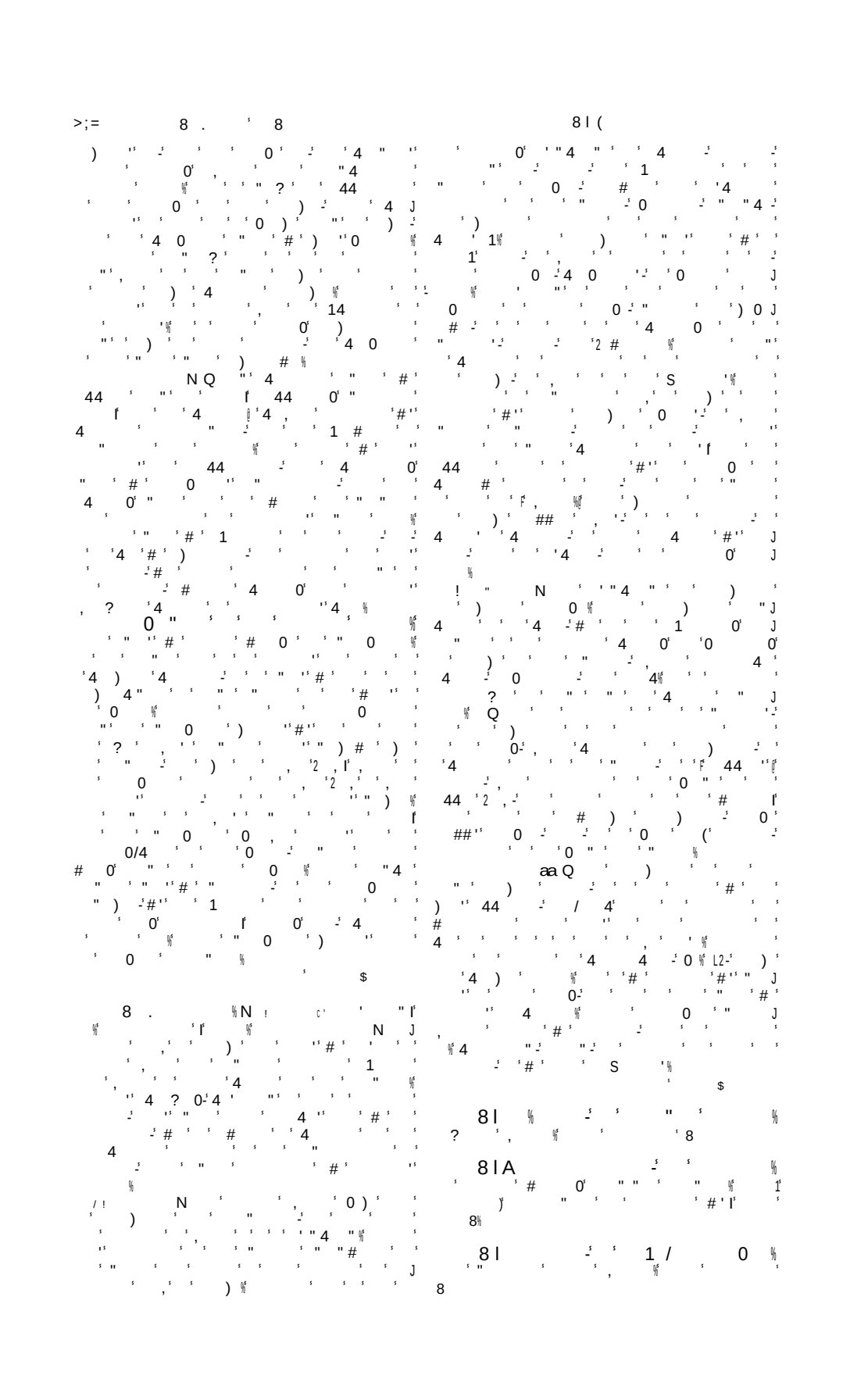

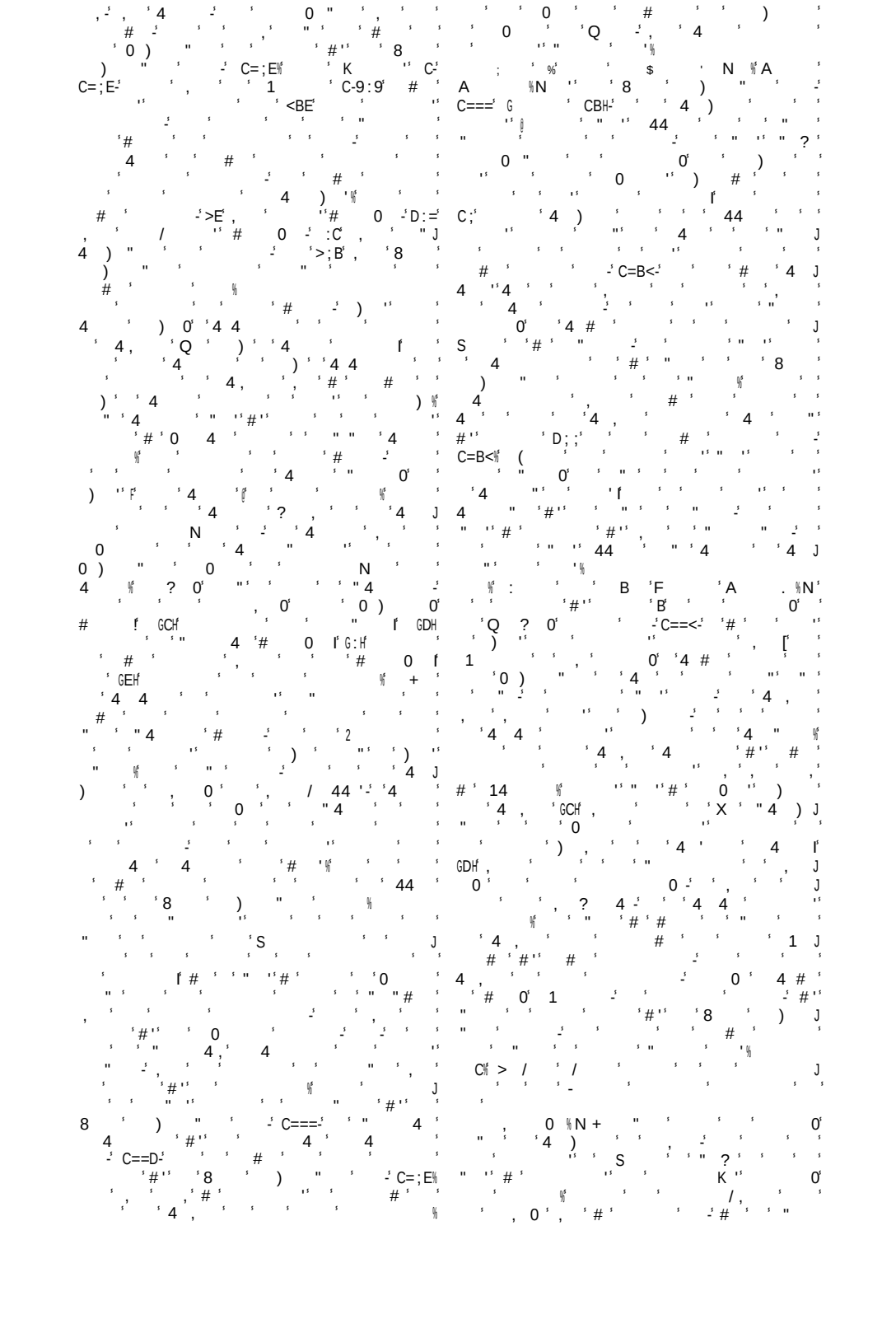

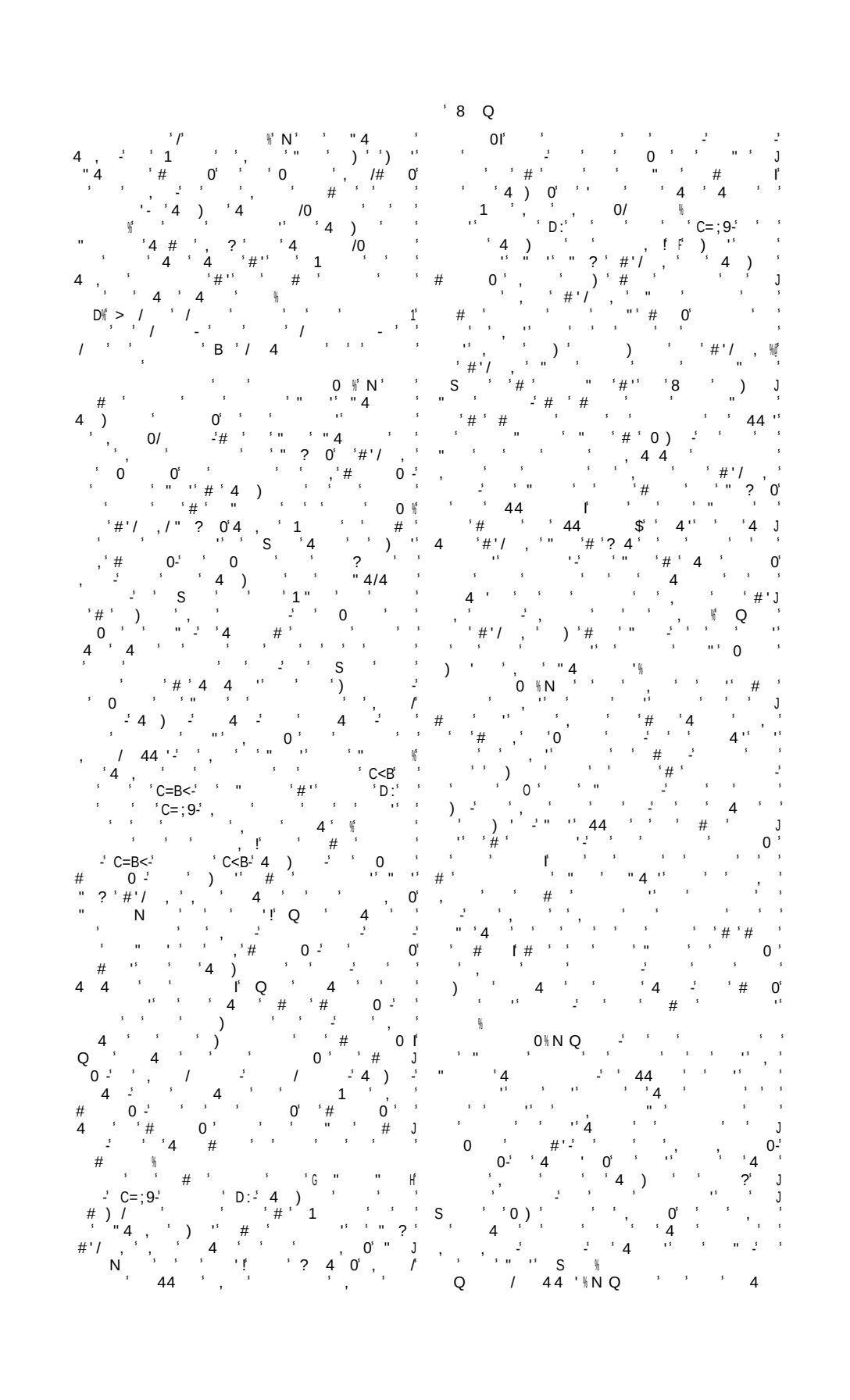

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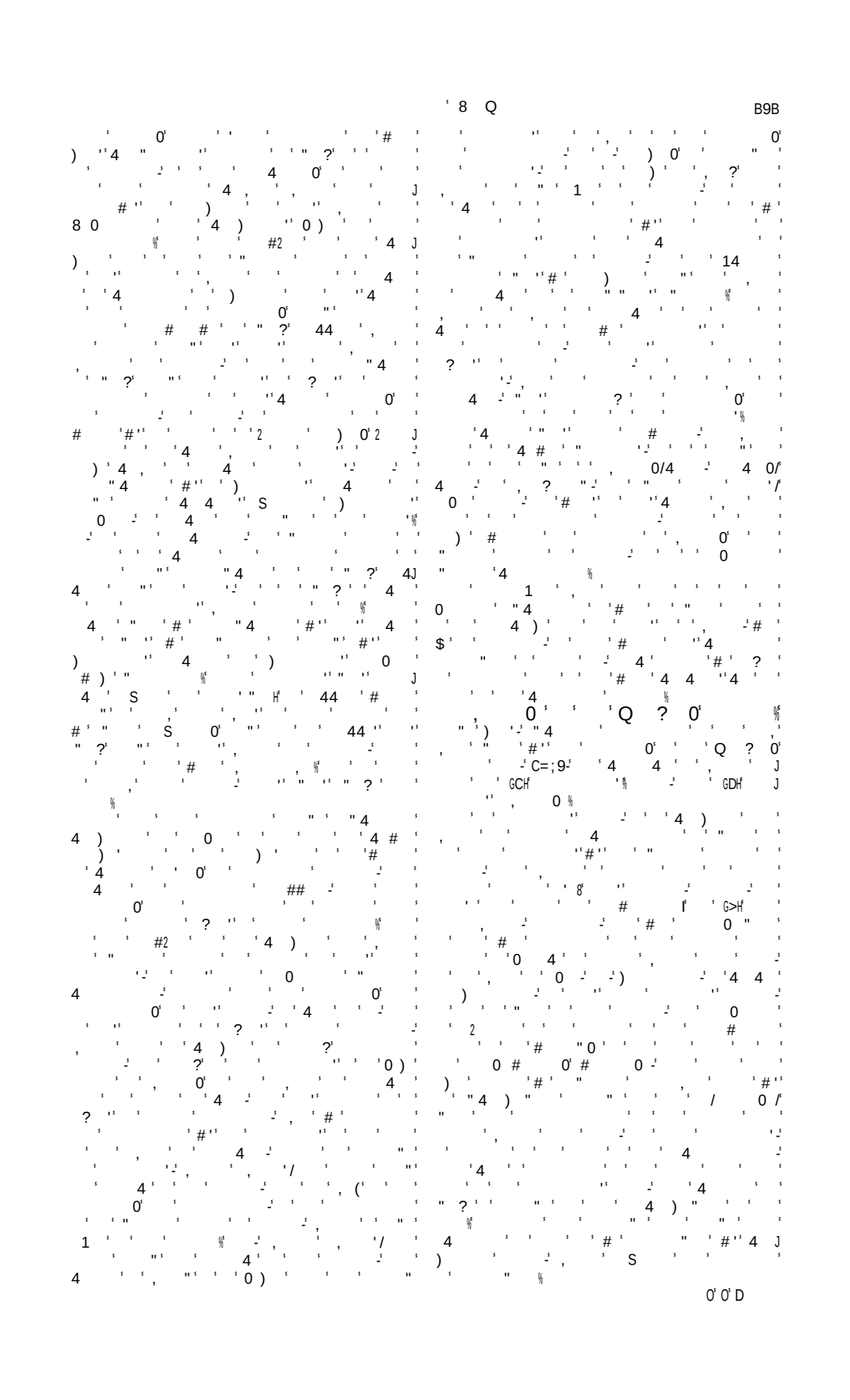

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SANTA AQUEDA, in Spain.—Cold sulphated and chalybeate waters. *See* MINERAL WATERS.

SANTA BARBARA, in Southern California.—A very mild, equable climate, on the Pacific coast. Temperature—mean annual, 61° F.; winter mean, 54°. Rainfall, 16 inches. Used for phthisis and other pulmonary affections. *See* CLIMATE, Treatment of Disease by.

SANTA FÈ. — The capital of New Mexico, at an altitude of 7,013 feet, in a dry and arid region. Lacks equability of temperature. Mean annual temperature 48° F.; relative humidity percentage, 45. More suitable for a winter than a summer residence for invalids. It is principally recommended as a winter residence for pulmonary affections on account of its combining a certain degree of warmth with altitude. *See* CLIMATE, Treatment of Disease by.

SARATOGA, in Saratoga County, New York, U.S.A.—Alkaline chalybeate and muriated alkaline waters, containing traces of iodine and bromine. The springs of Ballston, a few miles from Saratoga, are of a like character. *See* MINERAL WATERS.

SARCINA (*sarcina*, a pack or bundle).—This is a morphological term applied to various species of micro-organisms belonging to the group of Schizomycetes, which, developing by fission in three planes at right angles to one another, form more or less cubical aggregates of 4, 8, 16, 32, or 64 cocci, having the appearance of corded 'bales' or 'packets.' *See* MICRO-ORGANISMS.

So far as is known at present, these bodies are not pathogenic, but merely find a suitable habitat in the diseased conditions with which they are associated, but of which they are not the cause.

The most important species of sarcina in human pathology are the following:—

1. **Sarcina ventriculi.**—This species, first discovered by Goodsir in 1842, is of frequent occurrence in the stomach, and in the vomit of gastric dilatation from pyloric obstruction; in some cases of gastric ulcer and carcinoma without dilatation; and in rare cases of gastric catarrh. Sarcinæ are not sufficiently constant to be of much diagnostic value, and are certainly not pathognomonic of a dilated stomach, as has been supposed. Their appearance is usually associated with a state of fermentation of the gastric contents, which appear like yeast, and are of an acid reaction and smell; but it would seem that the organism is developed in the progress of the fermentation, and is not the actual cause of the condition, for, when placed in suitable surroundings, living sarcinæ have not been observed to set up fermentative changes, and cases are recorded of their occurrence in vomit that showed no signs of fermentation.

Sarcinæ are easily detected under the microscope. A drop of liquor potassæ added

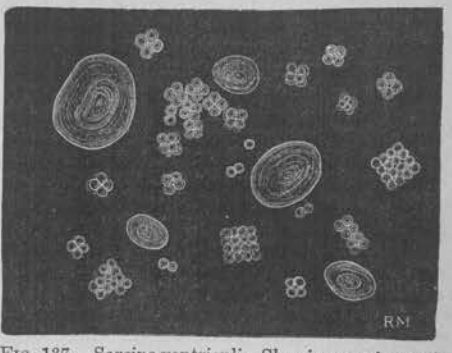

FIG. 137.—Sarcina ventriculi. Showing sarcinæ and starch-granules in vomited matter. × 400 diam.

to a fragment of vomit on the glass slide, and covered with thin glass, is sufficient to display their characteristic appearances. The constituent cells are of a diameter of about $\frac{1}{2500}$ of an inch (*see* fig. 137).

2. **Sarcina pulmonum.**—This species has been described as occurring in certain lung-states associated with suppuration. It is said to readily induce ammoniacal decomposition of the urine when introduced into this fluid; and in one case appeared to contain starch or cellulose in its composition.

3. **Sarcina urinæ.**—This species of sarcina is of much rarer occurrence, and has been occasionally found in the bladder. It is much smaller than the gastric species, and the 'bales' usually consist of a greater number of cocci.

Sarcinæ are also stated to have been found in the fæces, in the ventricles of the brain, in hydrocele fluid, in gangrenous intestines, in cholera stools, and even in the blood.

W. H. ALLCHIN.

SARCOCELE (*σάρξ*, flesh; and *κήλη*, a tumour).—A name for any solid enlargement of the testes. *See* TESTES, Diseases of.

SARCOMA (*σάρξ*, flesh).—A tumour composed of some modification of embryonic connective tissue. *See* TUMOURS.

SARCOPTES SCABIEI. — A synonym for acarus scabiei. *See* ACARUS.

SATURNISM (*saturnus*, lead). — A synonym for lead-poisoning. *See* LEAD, Poisoning by.

SCABIES (*scabies*, scab, mange). — SYNON.: Itch; Fr. *Gale*; Ger. *Krätze*.

DEFINITION.—A simple inflammation of the skin, produced by the irritation of the *acarus scabiei* and the scratching of the sufferer. The disease is contagious, as the

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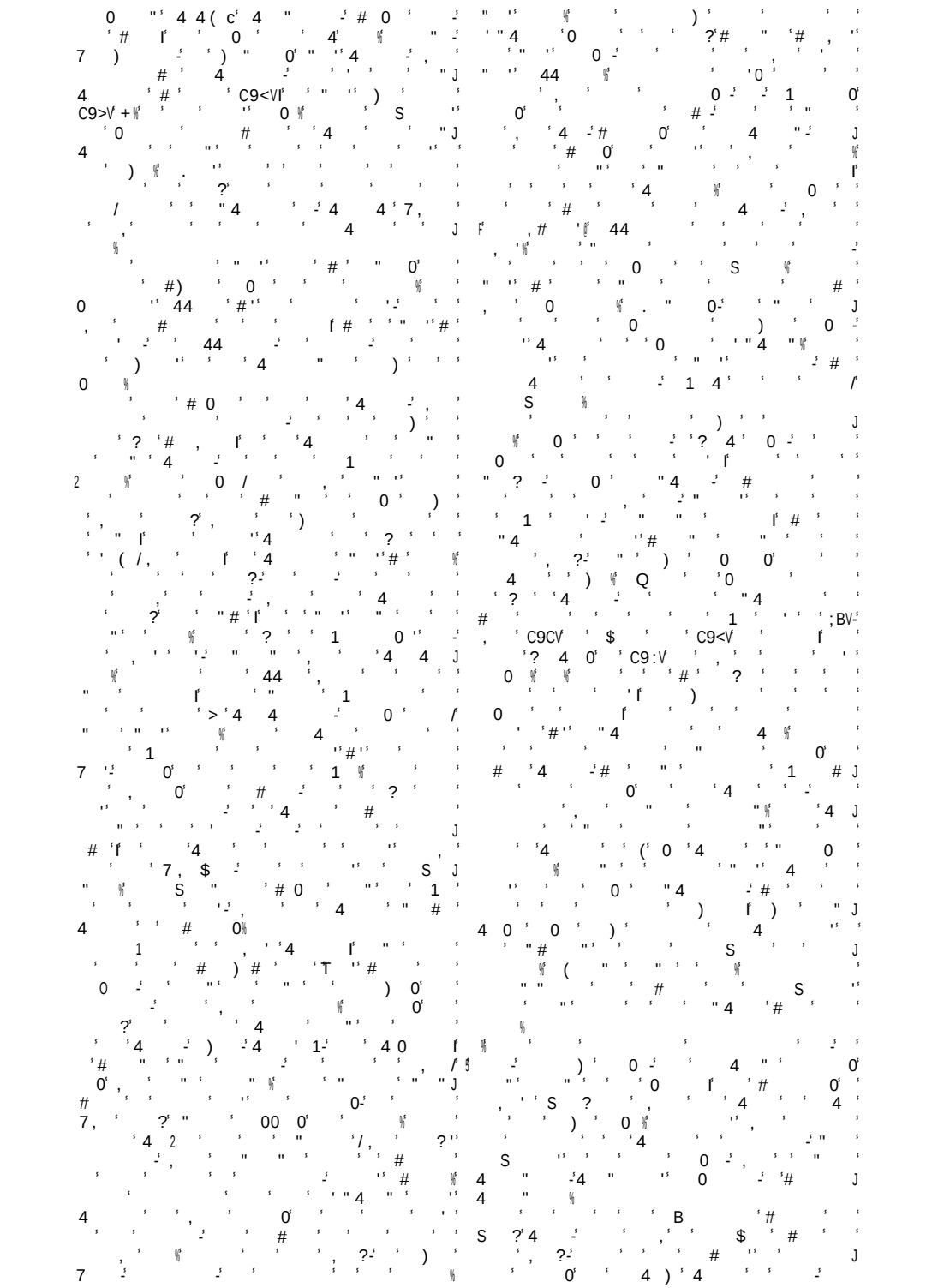

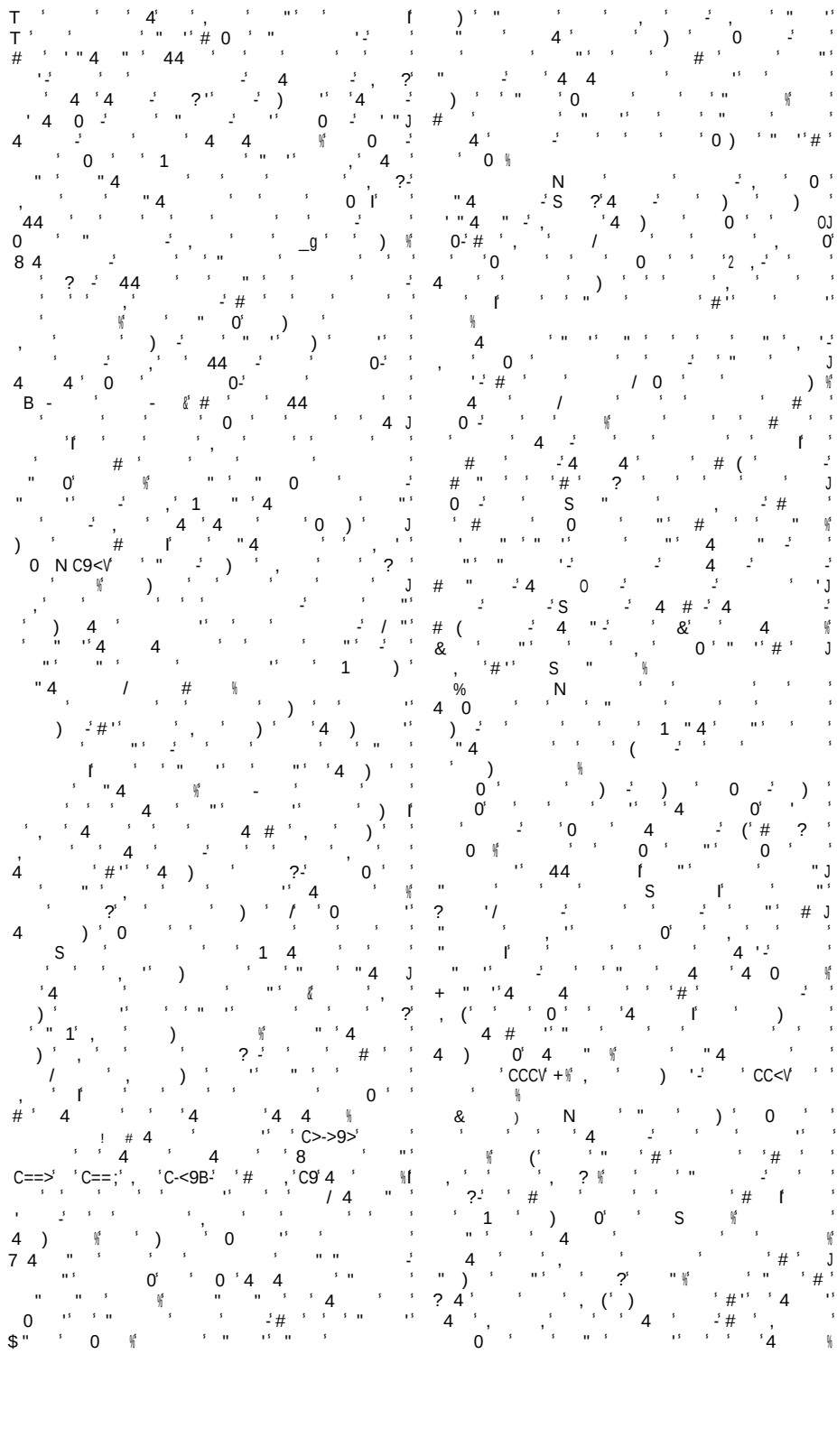

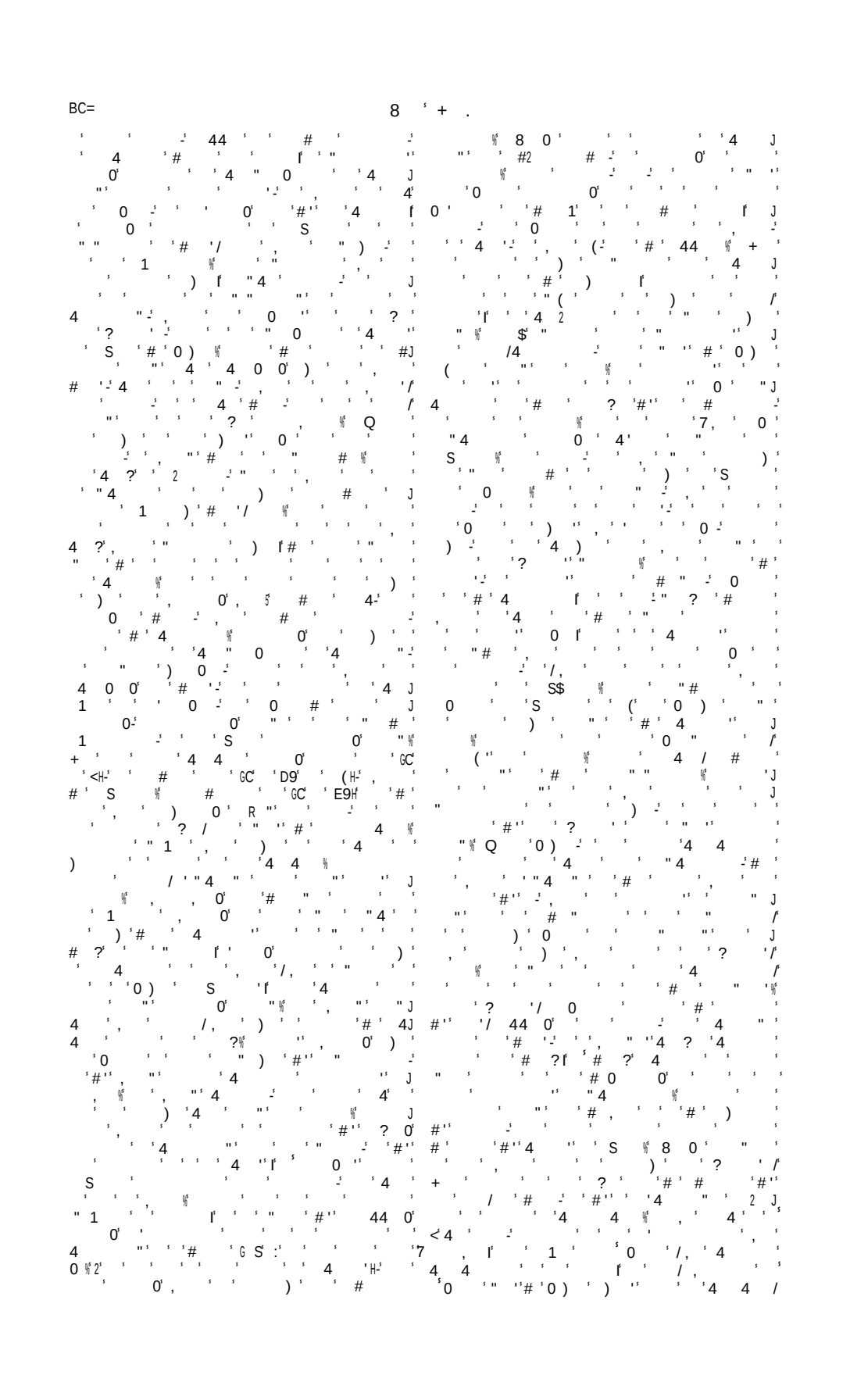

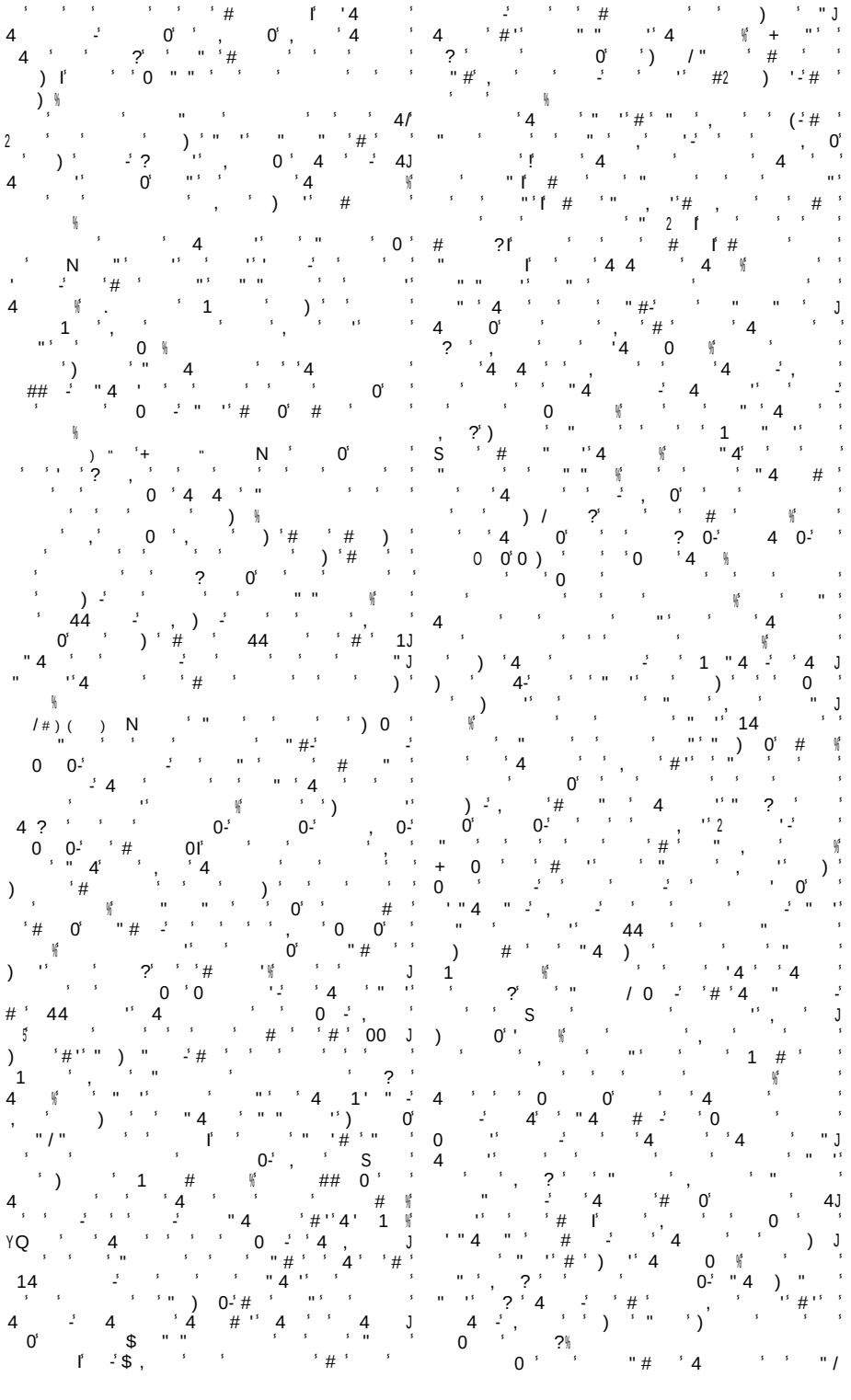

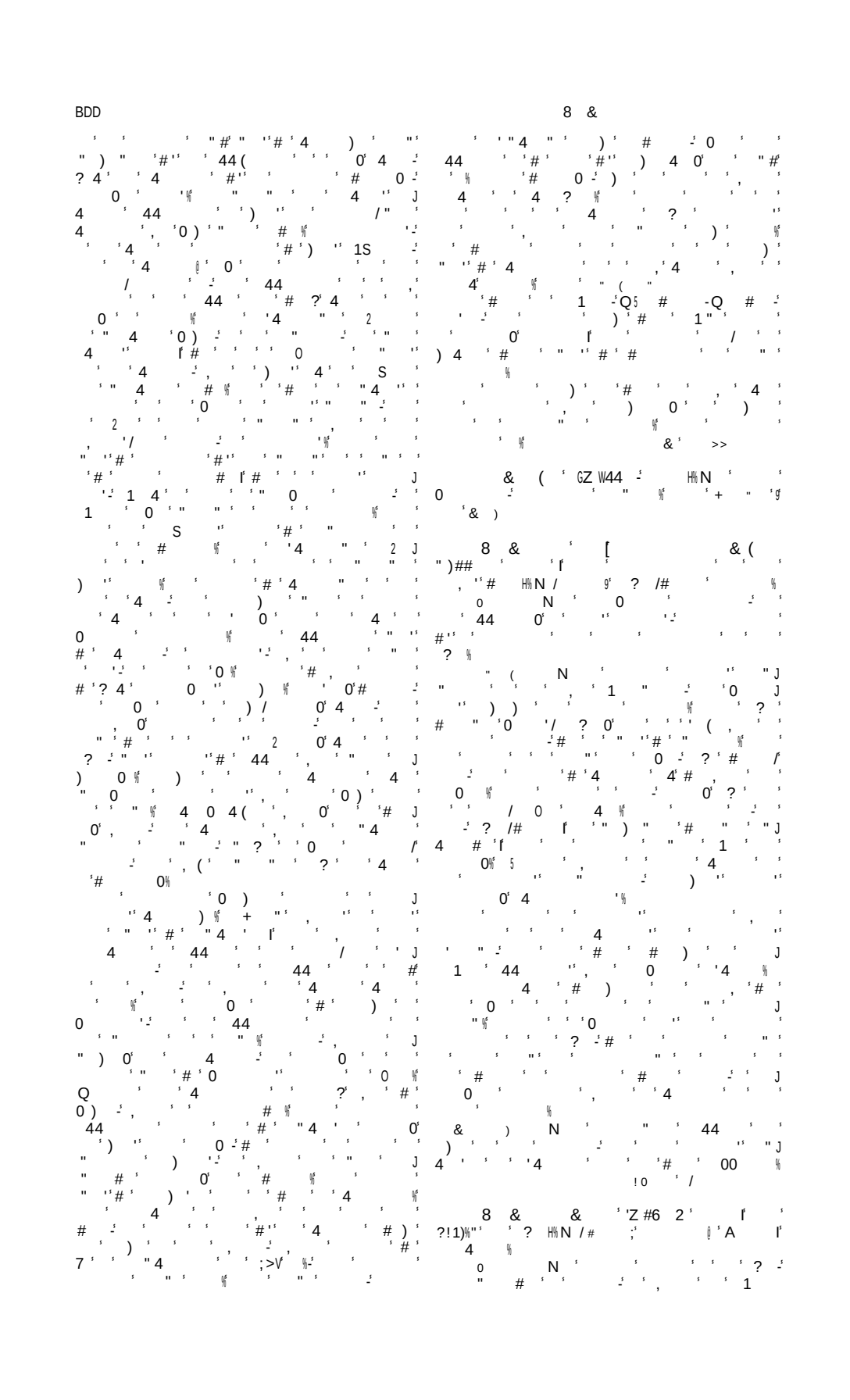

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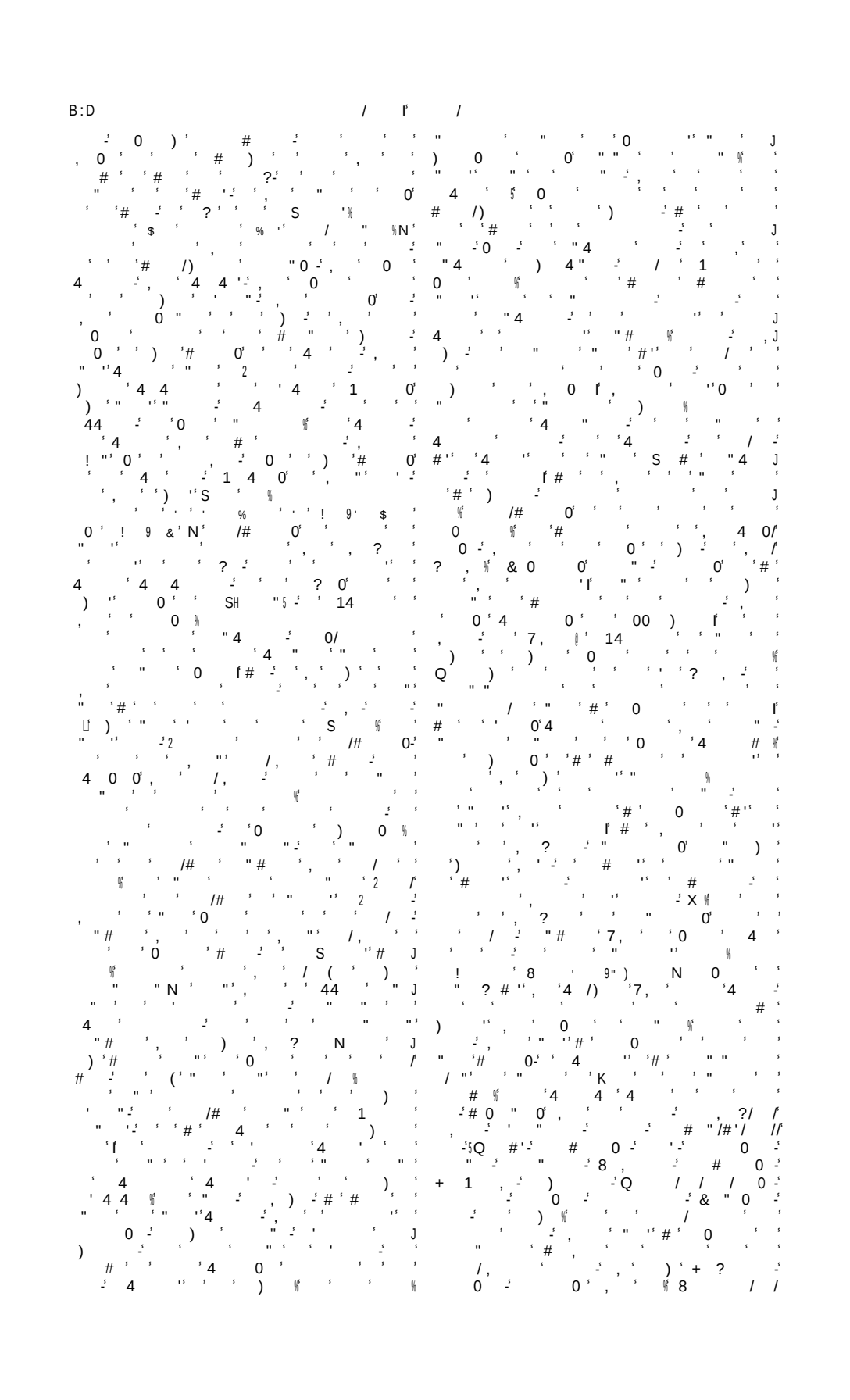

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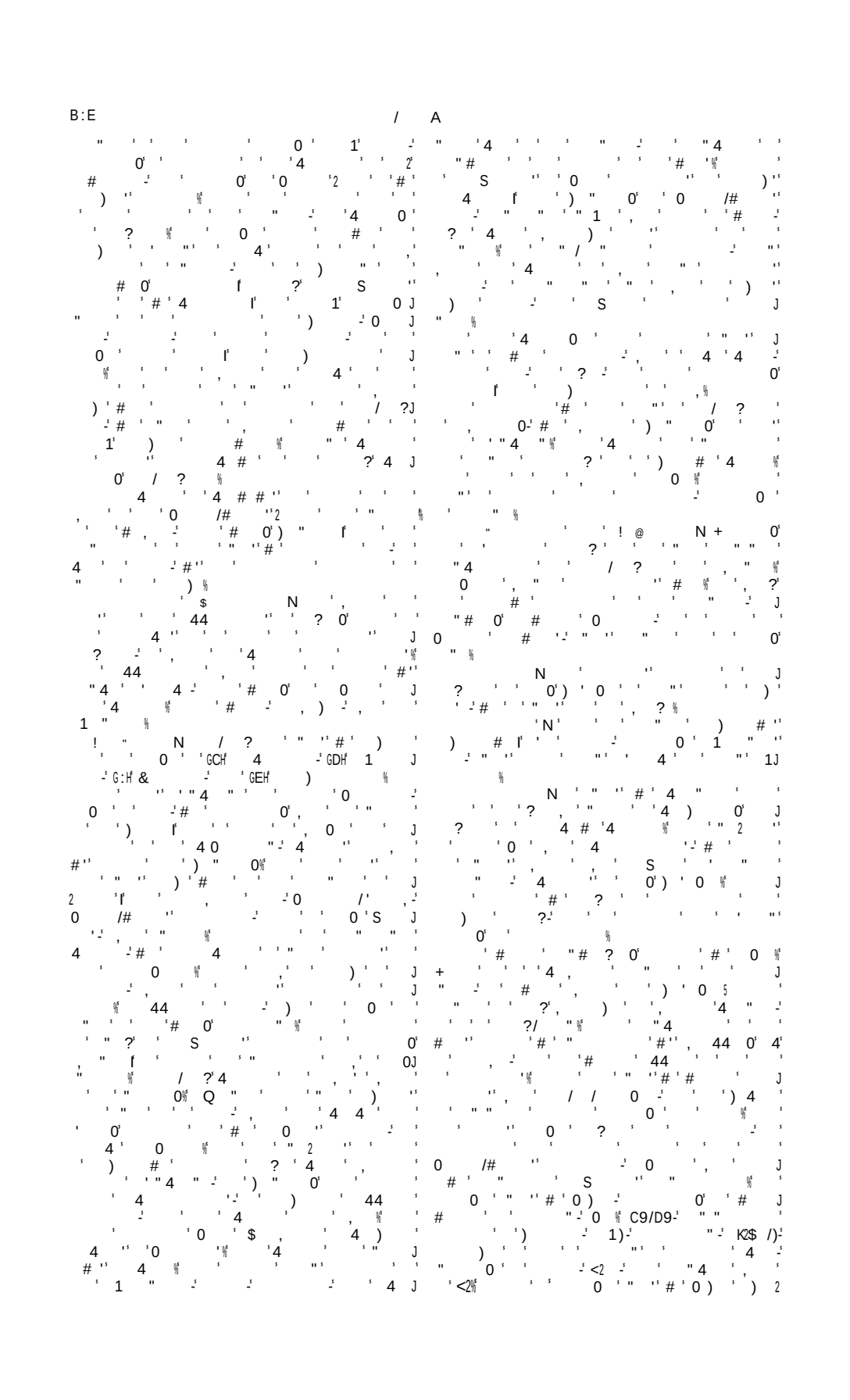

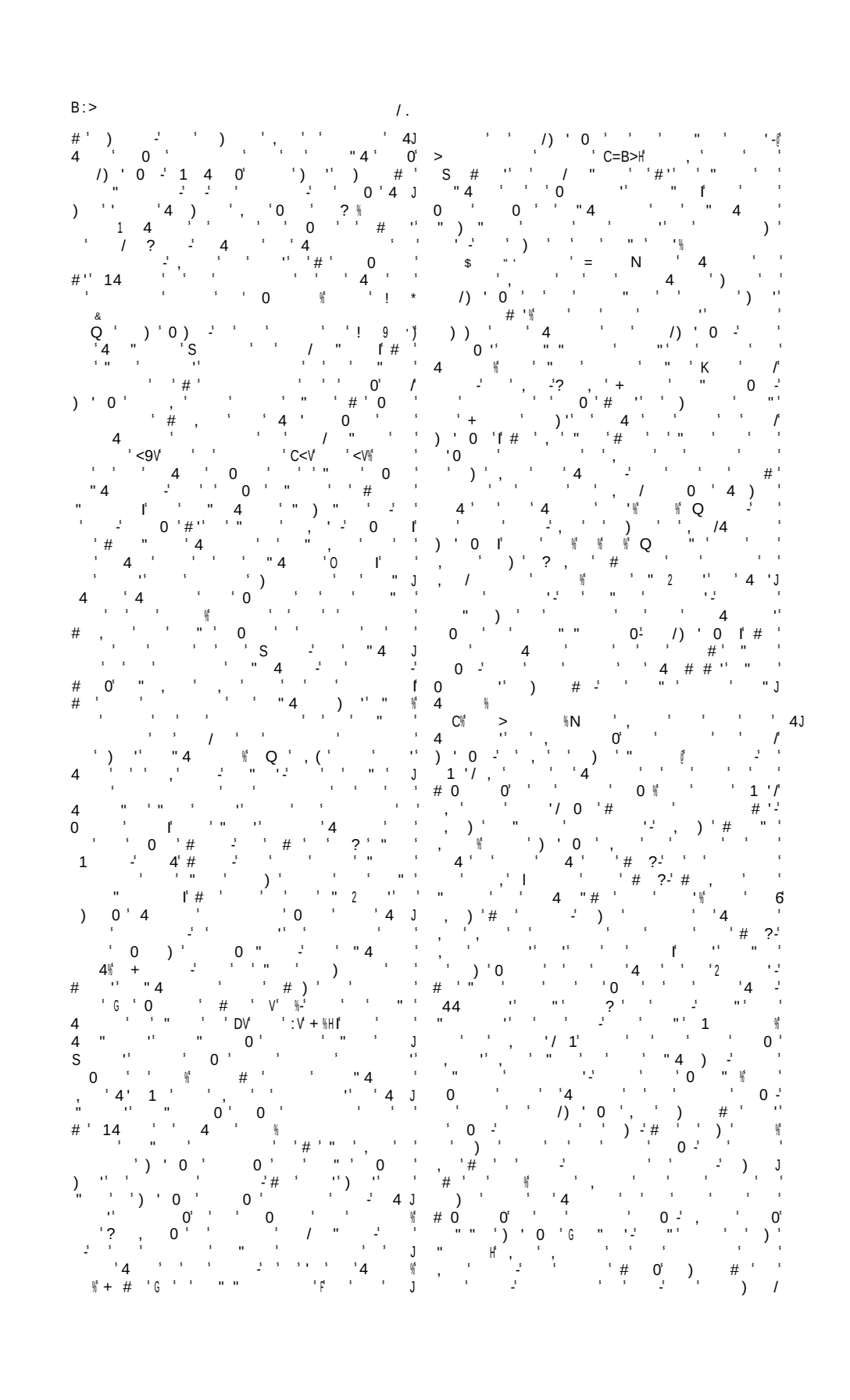

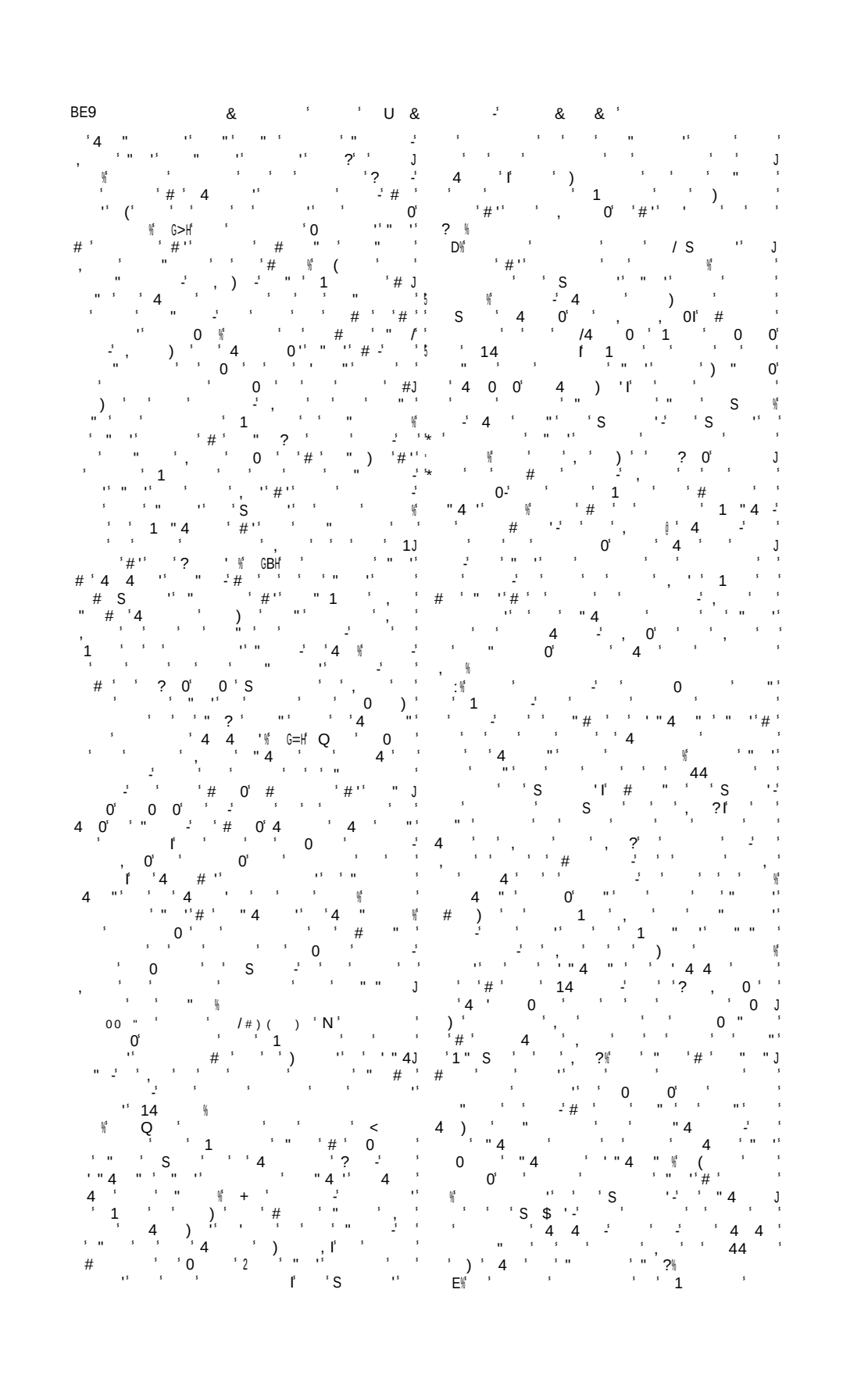

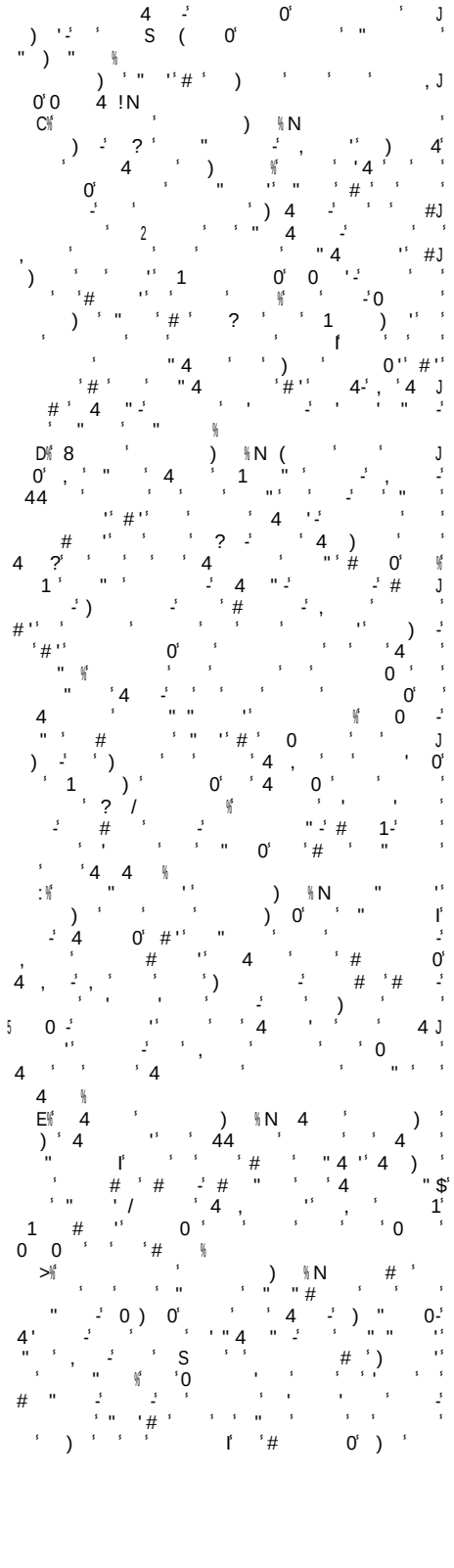

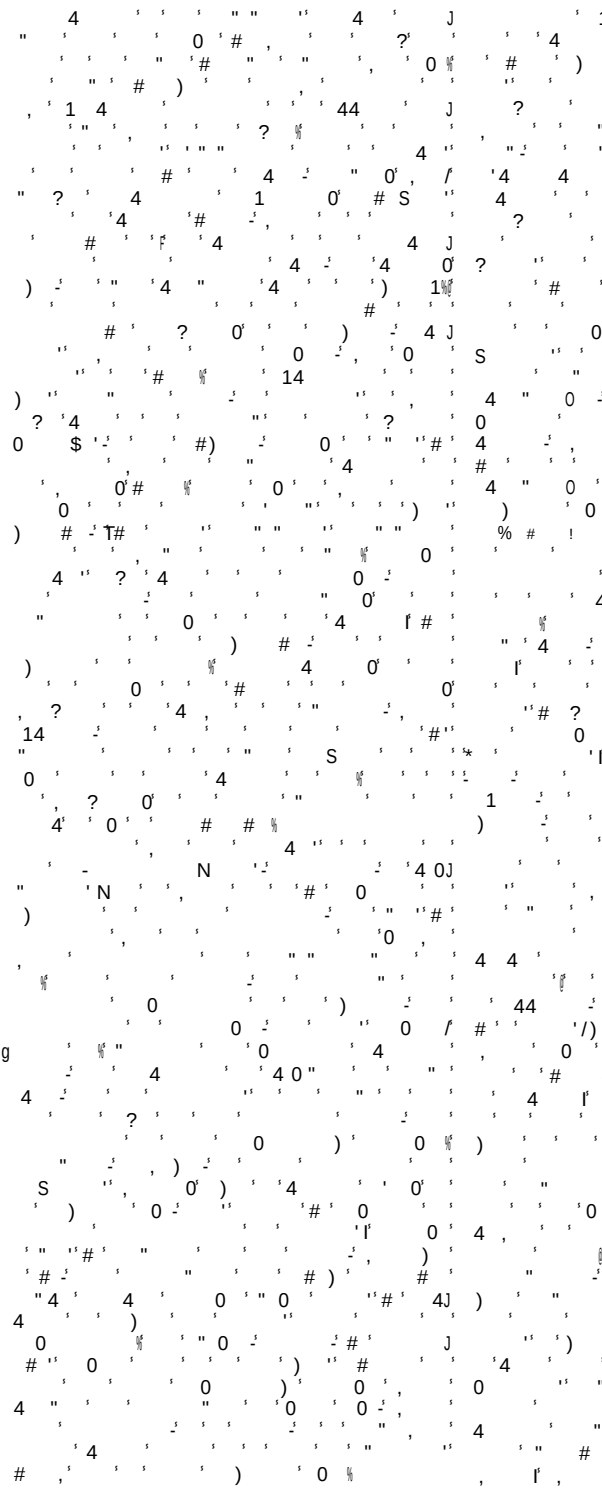

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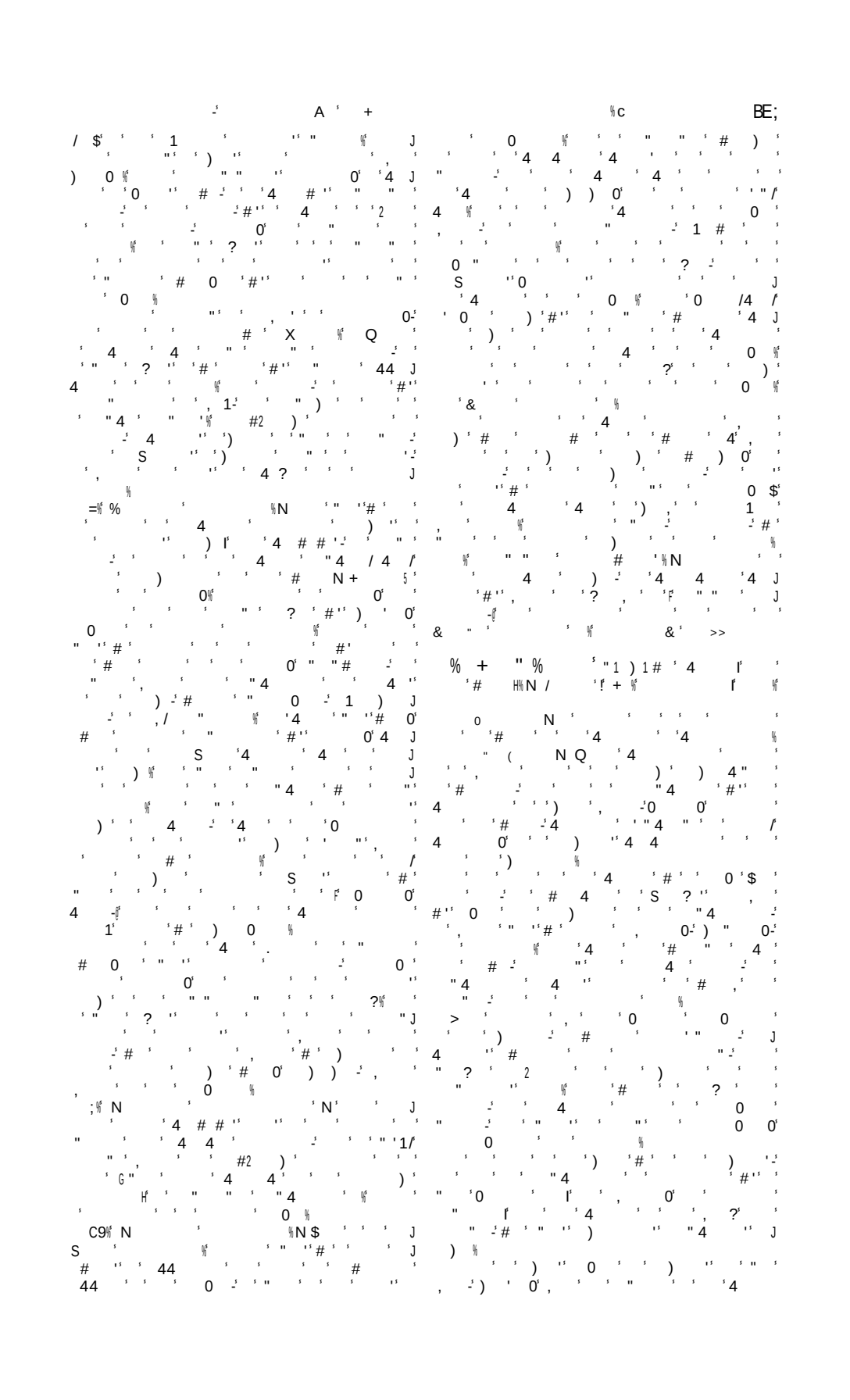

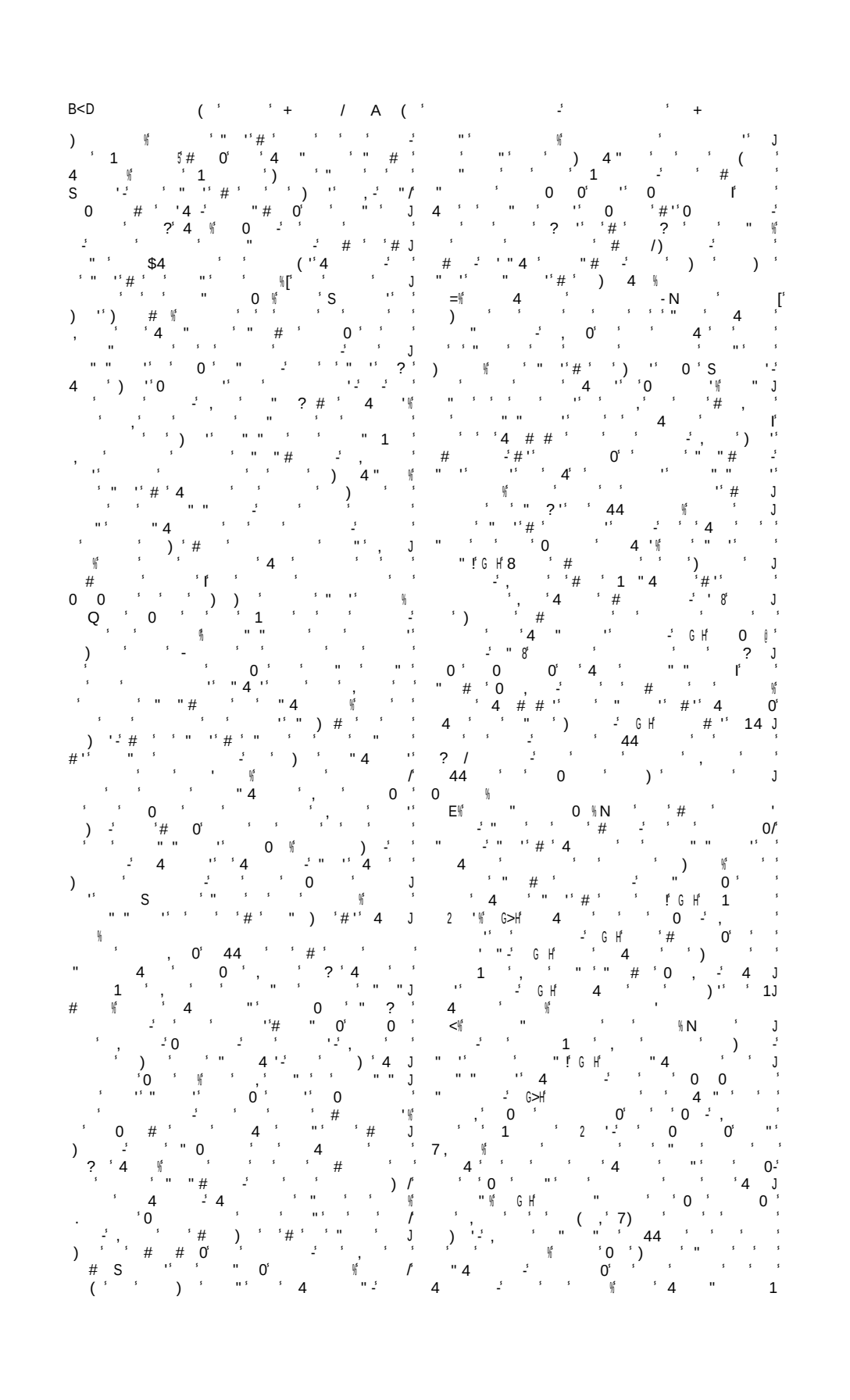

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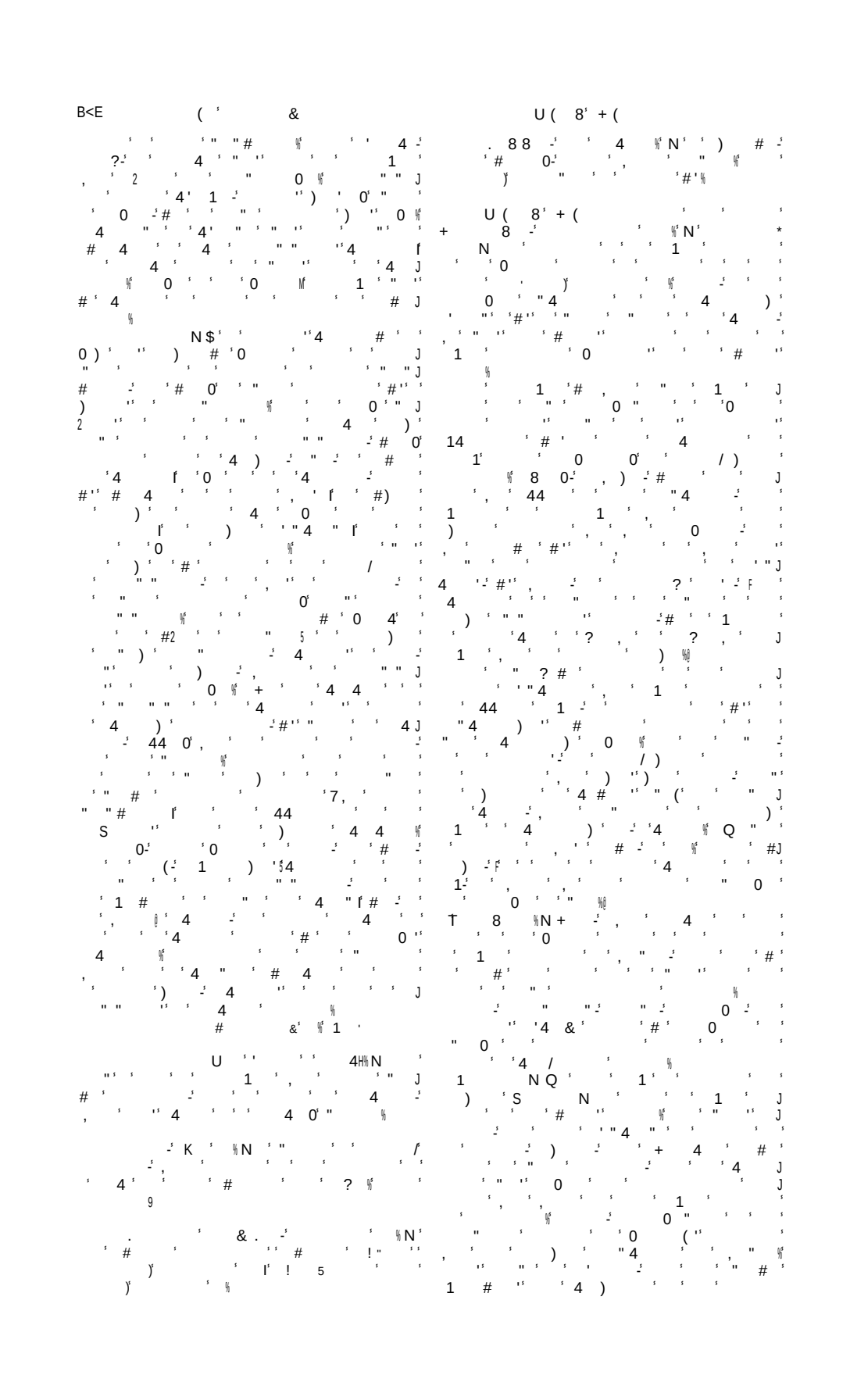

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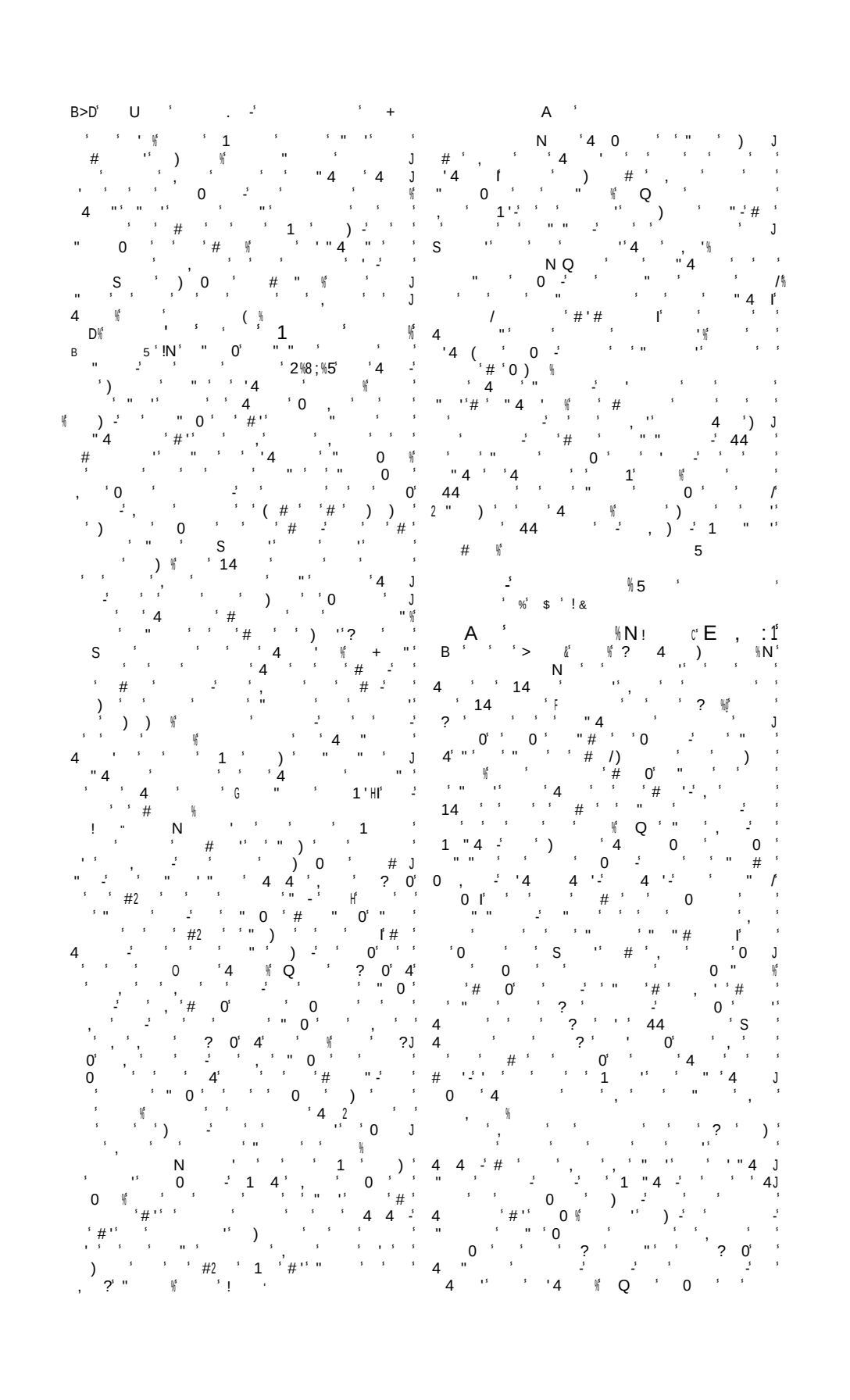

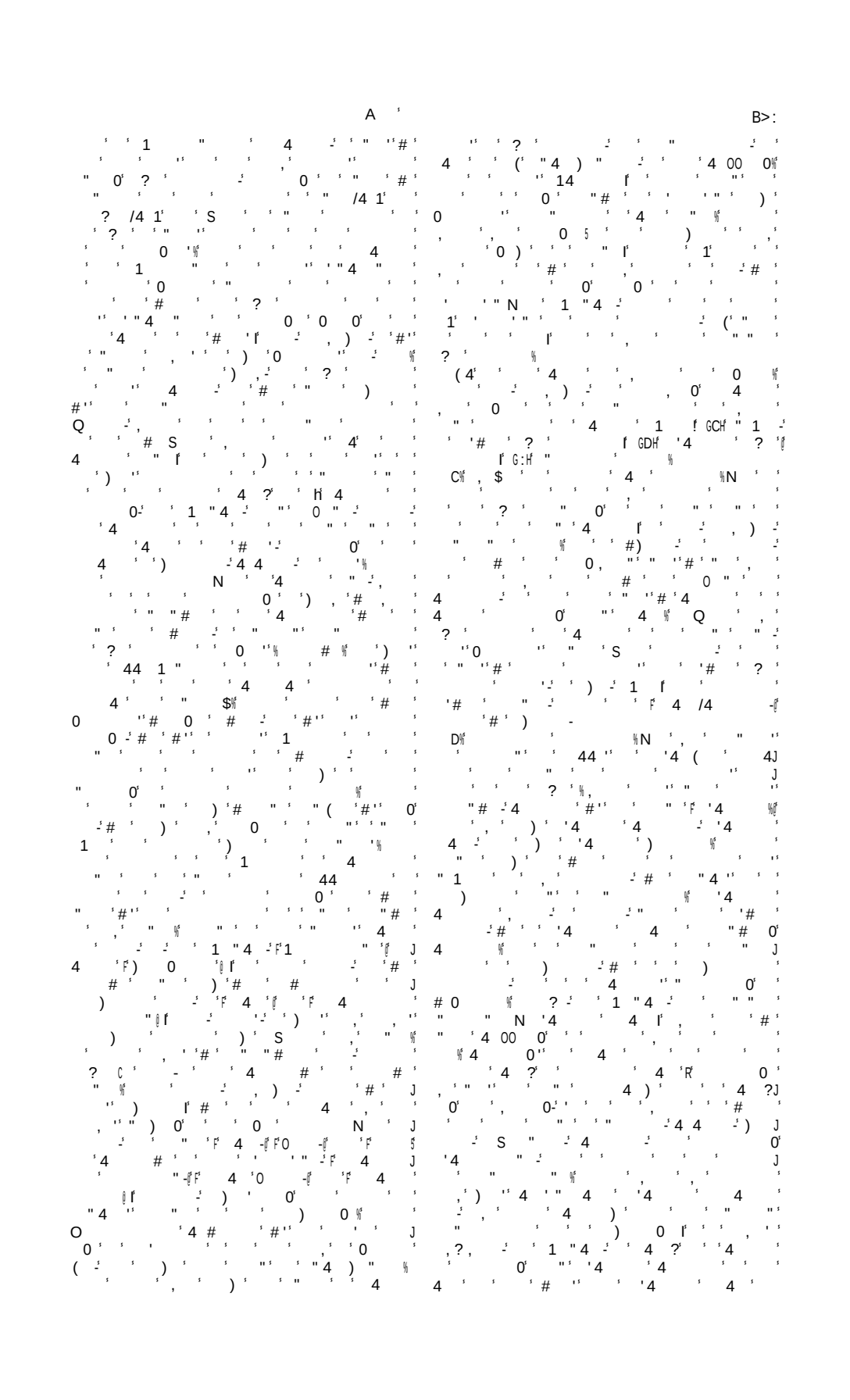

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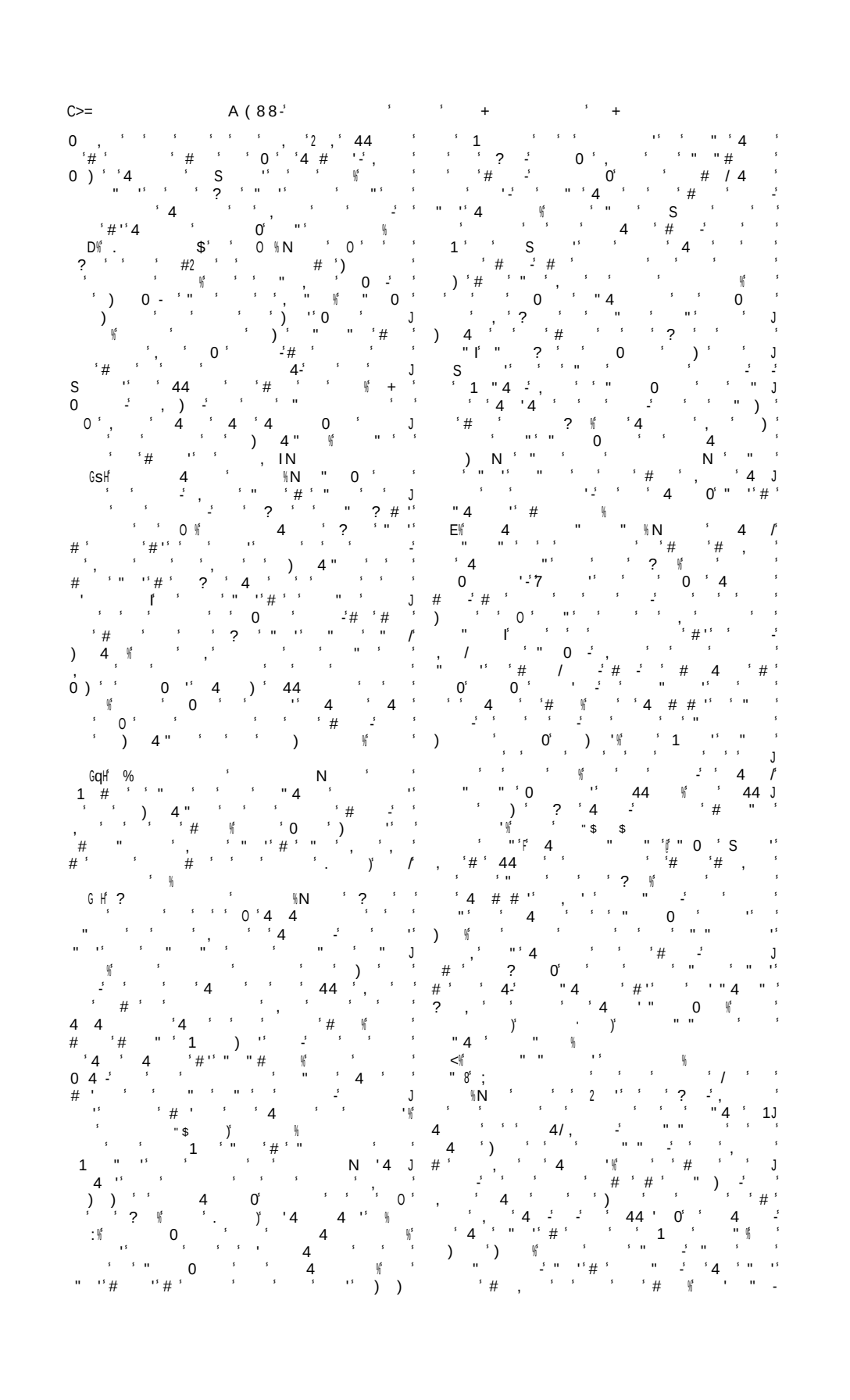

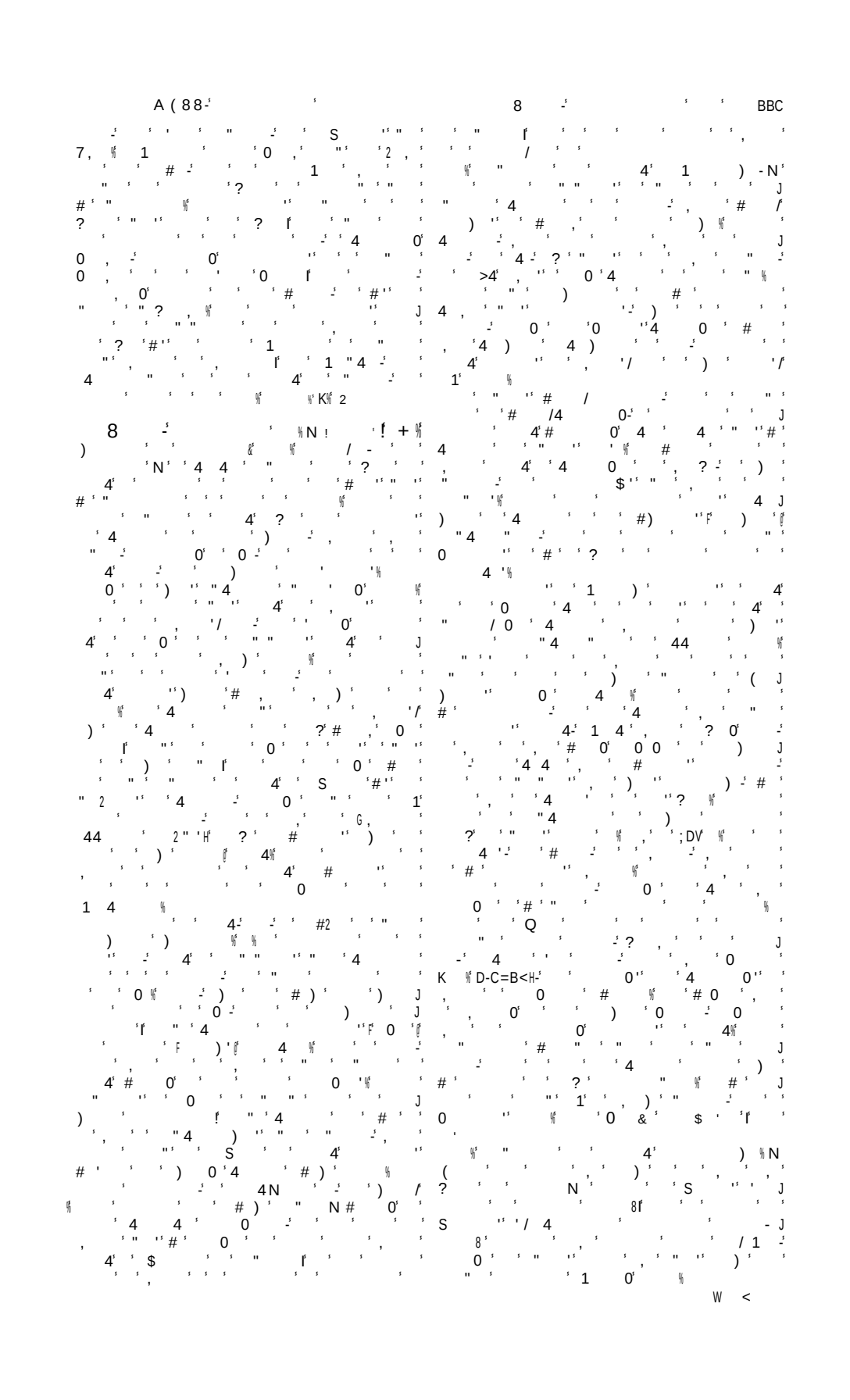

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observe is accuracy of adjustment of the ivory pad of the spring over the radial artery. This can be best done by marking the position of the artery with ink, and then carefully adjusting the spring. Secondly, the pressure on the artery must be regulated by means of the pressure screw, so as to obtain the greatest amplitude of movement by the lever, and the record of all the waves of the pulse. Thirdly, the friction between the recording pen and the receiving plate, on which the trace is recorded, must be reduced to a minimum. Smoked glass and paper are the best receivers; pens that write with ink are apt to blur the finer features of the trace. The tracings on smoked glass or paper are fixed and rendered permanent by varnish; the tracing papers, which should be well enamelled, may be smoked by being held over burning paraffin or camphor, or even over an ordinary vesta match. When the traces are recorded, they may be fixed by varnish made of gum benzoin, or Burgundy pitch in methylated spirit (1 in 8), or ordinary tincture of tolu.

Uses.—The applications of the sphygmograph to clinical inquiry are numerous and important. Precision is given to the study of the pulse, and by the aid of a graphic representation of its form the finger is taught what to feel. A pulse-trace (*see* Pulse, *which should be read with this article*) shows at a glance the rate, regularity, and equality of the heart-beats. Irregularities, and especially inequalities, that escape the finger, are registered; and indications as to pulse-tension and heart-strength, most important for prognosis and treatment, are obtained. In acute visceral inflammations, for instance, slight inequalities in the pulsations otherwise unrecognisable may be recorded, and the first signs of heart-failure, and the necessity for stimulants, thus suggested. Again, the undulatory pulse of a ventricle, too weak to resist respiratory influences, is disclosed in the tracing; and prognosis and treatment may be correspondingly modified.

Indications.—The evidence yielded by the sphygmograph mainly concerns: (1) The mode of the heart's contraction. (2) The condition of the peripheral circulation. (3) The state of the arteries and their coats. (4) Valvular diseases of the heart.

1. The Mode of the Heart's Contraction.—The sphygmographic tracing shows this by the line of ascent. When the heart-muscle acts suddenly and vigorously, the line is vertical and lofty, and terminates in a pointed summit-wave. Unless the vessels are over-full of blood, there follow well-marked tidal and dicrotic waves. On the other hand, when the heart's contraction is feeble, the line of ascent is less vertical and lofty; the summit wave is less distinct; and the tidal and dicrotic waves are less, or the former is blended with the summit wave. The pulse, moreover, unlike the pulse of a vigorous ventricle, is easily obliterated by pressure. A note of the pressure at which the most perfect trace is collected should always be made, as it enables the observer to compare results at different times.

2. The Condition of the Peripheral Circulation.—The easy or difficult passage of the blood through the arterioles and capillaries, causing low or high pulse-tension, is estimated by the pressure required to develop or to obliterate the three waves, but more especially the tidal and dicrotic waves. Obstructed peripheral circulation is manifested by increase of the tidal wave, diminution of dicrotism, and lessened height of line of ascent and summit wave (fig. 139). The heart, apart from febrile or nervous excitement, contracts less suddenly under these conditions. On the other hand, in easy and quick capillary circulation, such as occurs in

Fig. 139.

fevers, the sudden heart-contraction causes a more vertical and higher line of ascent, exaggerates the summit wave, lessens the

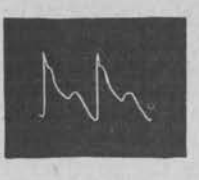

Fig. 140.

Fig. 141.

tidal wave, and fully develops the dicrotic wave (fig. 140). In such conditions the fully dicrotous and hyperdicrotous traces are recorded (fig. 141). The rapid onflow of blood is, moreover, shown by the more sudden fall of the line of descent. It is by the comparative study of the three waves, and the pressure required to record them fully, that we obtain valuable indications as to heart-strength and pulse-tension in acute diseases, and in the earliest stages of some chronic affections.

3. The State of the Arteries.—There are three chief conditions of the arteries that modify the pulse: (*a*) The state of the *muscular* coat; (*b*) *degenerative* conditions of the arterial walls; and (*c*) the presence of *aneurysm*.

(*a*) When the *muscular* coat is contracted,

the artery imparts to the finger a hard, wiry sensation, which shows in the trace by a short line of ascent, and the blending of the summit and tidal waves in an oblique line of descent, scarcely broken by dicrotism (fig. 142). In the opposite condition of relaxed

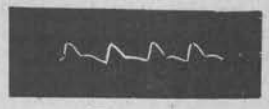

FIG. 142.

arterial coats, the dicrotic and summit waves are enlarged, and the tidal waves lessened. These changes can be experimentally illustrated by the application of cold and heat to the surface of the body. The cold and hot stages of ague also show the two states.

(*b*) *Inflammatory* and *degenerative* processes lead to rigidity of the arteries, whereby

FIG. 143.

the modifying influence of their elasticity on the blood-movement is lost. The blood-wave in the radial artery consequently approaches more to that imparted by the heart's systole. In these conditions the pulse often beats visibly, so that we are prepared for the amplitude of the trace. The tidal wave is large, nearer to, and often blended with the summit wave, while the dicrotism which occurs early in the line of descent is badly marked. The presence of these peculiarities often leads to the early diagnosis of unsuspected atheroma of the great vessels (fig. 143).

(*c*) When the sac of an *aneurysm* is seated on a main trunk after its origin from the aorta, it acts as an elastic bag, and so modifies the pulse-form by rendering the line of ascent oblique, diminishing or abolishing the summit wave, modifying the dicrotism, and more or less converting the three waves into a simple curve. To the finger these changes mean retardation (oblique line of ascent) and diminution of force (loss of summit wave). Such peculiarities in the left radial artery are produced by an aneurysm of the left subclavian, or in the right radial by innominate aneurysm. When the aneurysm is connected with the thoracic aorta in its ascending portion, there is frequently a dissimilarity between the two radial pulse-traces, which is persistent, one being smaller than the other, more vibratory, or more easily obliterated by increased pressure. The pulse usually more affected is the right, as the aneurysm tends to implicate the innominate artery. In aneurysm of the transverse portion of the arch, the left pulse is more commonly diminished in force and amplitude (figs. 144 and 145). In aneurysms of the

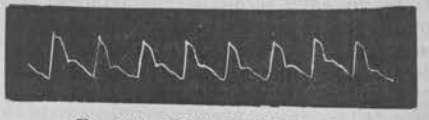

FIG. 144.—Right Radial Tracing.

FIG. 145.—Left Radial Tracing.

descending thoracic and abdominal aorta, the dicrotic wave is often much increased in both pulses, while the right radial yields usually the more normally developed trace.

These signs may be more or less simulated by pressure of tumours on the arterial trunks, or by their partial obstruction by clots. The sphygmographic signs of aneurysm, therefore, require to be confirmed by the use of the ordinary means of diagnosis. In some cases, however, the pulse-traces alone suffice to indicate the lesion and its seat.

4. Valvular Diseases of the Heart.—Valvular diseases of the heart generally influence the pulse-trace. In *aortic regurgitation* this is strikingly seen (fig. 146). The strong, dilated ventricle contracts suddenly on a large charge of blood, and consequently there is a lofty line of ascent, ending in a pointed summit wave. The tidal wave is small in proportion to the trace; and the dicrotism, which occurs later than normal in the line of descent, is generally much diminished, on account of the leakage into the ventricle interfering with the rebound of the blood-column from the closed valves. The dicrotic wave, thus starved, is followed by a rapid fall in the tracing, showing the quick emptying of the artery. It is this contrast between the height of the summit wave and the rapid fall of the trace, unbroken by any *sustaining* wave, that gives the pulse its splashing and collapsing character. These features, the small dicrotism and the rapid fall, indicate the amount of regurgitation. In some cases of this valve-lesion the tracing shows a well-marked tidal wave and a fairly developed dicrotic wave; and increased pressure by the spring of the

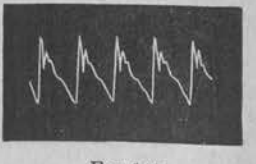

FIG. 146.

sphygmograph, instead of obliterating the trace as usual, shows that there is a fair amount of tension. Such features commonly occur in older persons, in whom the valve-defect is small and due to atheroma, and not to rheumatism, and the pulse-form is modified by the addition of the characters of the pulse of degenerated arteries. When such features are observed in rheumatic cases, and the trace more resembles the normal form, they point to perfect compensation and small valve-defect

In *aortic stenosis* the trace testifies to the amount of the lesion. When the narrowing is extreme the summit wave is lost, the line of ascent becomes oblique and gradual, and the pulse is felt to be retarded. More commonly a break in the line of ascent marks the position of the summit wave, while above it rises the large tidal wave, due to the strong systole (fig. 147). Such pulse traces are called *anacrotic*, to distinguish them from the *katacrotic* traces with all their waves in the line of descent. In cases in which the obstruction is less in degree, the summit of the tracing may be forked by a sharp division between the summit and tidal waves. The dicrotic wave is lessened. The loss or checked development of the summit wave, followed by an exaggerated tidal wave, arising from a strong and often dilated ventricle, pushing a large blood-wave *gradually* into the arteries through the narrowed aortic orifice, are the characteristics of this lesion when pure. When it is associated with aortic regurgitation, the large tidal wave is still pronounced.

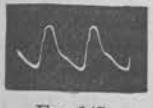

Fig. 147.

Mitral valve lesions, which are less immediately connected with the arterial blood-movement, present less decided characteristics.

In *mitral regurgitation* the tracing is often of the normal outline, and in such cases the compensation is fairly perfect. In some cases, in addition to great rapidity, the pulse is small and shabby, in striking contrast to the vigour of the impulse (fig. 148).

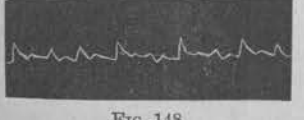

Fig 148.

The line of ascent is sloping, and the tidal and dicrotic waves poorly defined. In other cases great irregularity is the chief feature of the trace, a series of small, ill-developed pulse-waves being succeeded by large and well-formed pulsations. On analysis, the series of small, ineffectual heart-contractions correspond to inspiration, and the fuller and more vigorous ones to the respiratory pause. In other conditions similar irregularities are caused by the same influences. Dr. Burdon Sanderson, who first referred these irregularities to their cause, says: 'The mechanical effect of inspiration is to augment the quantity of blood contained in the pulmonary circulation, and hence to increase the frequency of the contractions of the heart. This increased frequency depends on the distended state of the auricles, in consequence of which the ventricles fill more rapidly during their period of relaxation. In this way the length of the diastolic pause is diminished, and the hurried action of the heart satisfactorily accounted for; but the question still arises, Why are the rapid beats which occur in inspiration also ineffectual? Very probably because the mitral valve does not close; the heart being distended with blood, its walls are kept apart to such an extent that the curtains do not meet. The ventricle contracts, but much of its blood is discharged into the auricle, to be returned to the ventricle as soon as its contraction is over. It is not until the effect of inspiration in keeping the auricles full ceases, that the curtains get near enough to allow the heart to make an effort sufficiently effectual to send a full tide of blood into the aorta, and thus relieve the distended pulmonary circulation.'

Similar peculiarities are occasioned by the same mechanism in tricuspid regurgitation and dilated heart.

In *mitral stenosis* the sphygmographic evidence is very important. The pulse-tracing shows irregularity in the line of descent, which often is greatly prolonged through a missed pulsation—a true intermission in the beat, and sometimes broken by the interpolation of a small, abortive pulsation (fig. 149). These abortive pulsations are due to over-distension of the auricle, causing premature auricular contractions, which propagate themselves to the ventricle, and so produce a ventricular contraction on a small charge of blood. They mostly occur during inspiration, from the causes above mentioned. The rhythmical relations between the contractions of the auricle and the ventricle are thus disturbed, and hence the features just described.

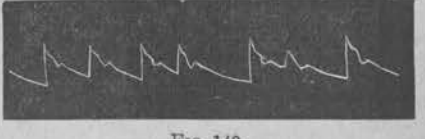

Fig. 149.

These are the special characters of the pulse of mitral stenosis. In some cases, where the stenosis is not great and the compensation perfect, the pulse is regular in time and form, or nearly so; but in these

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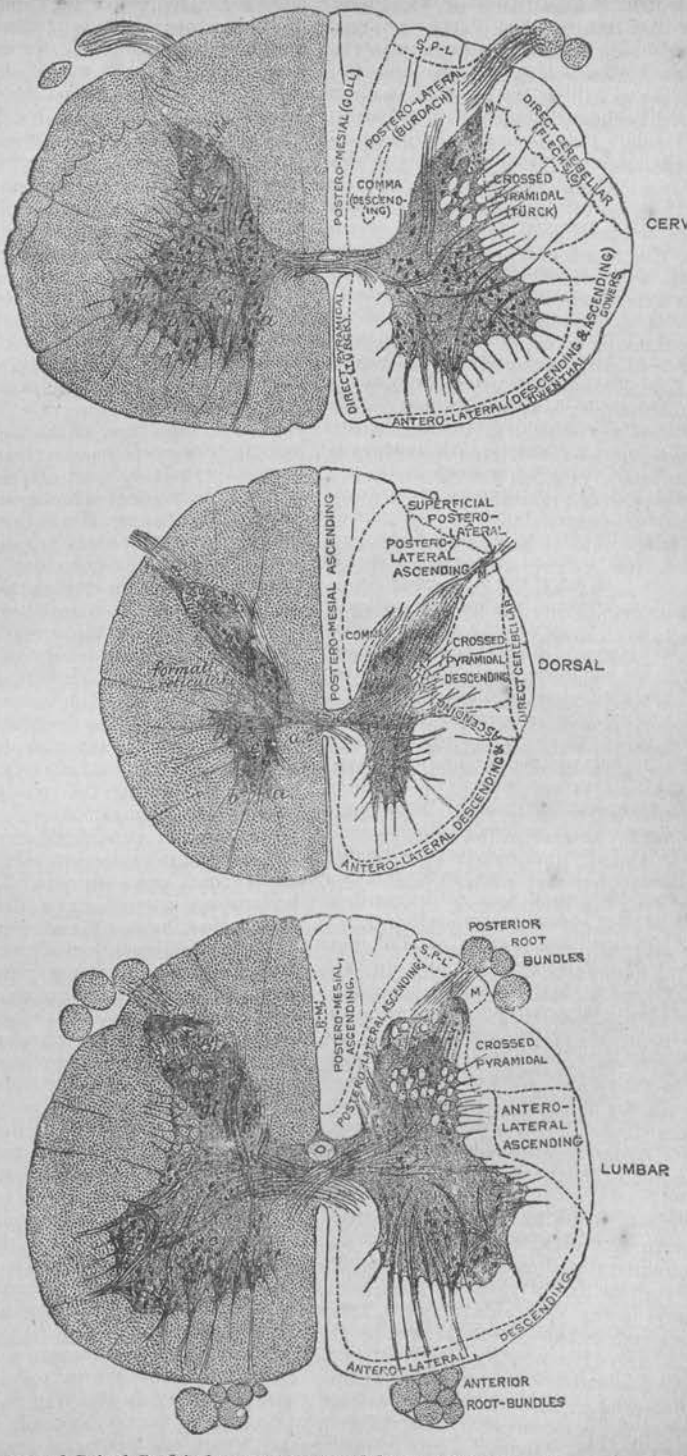
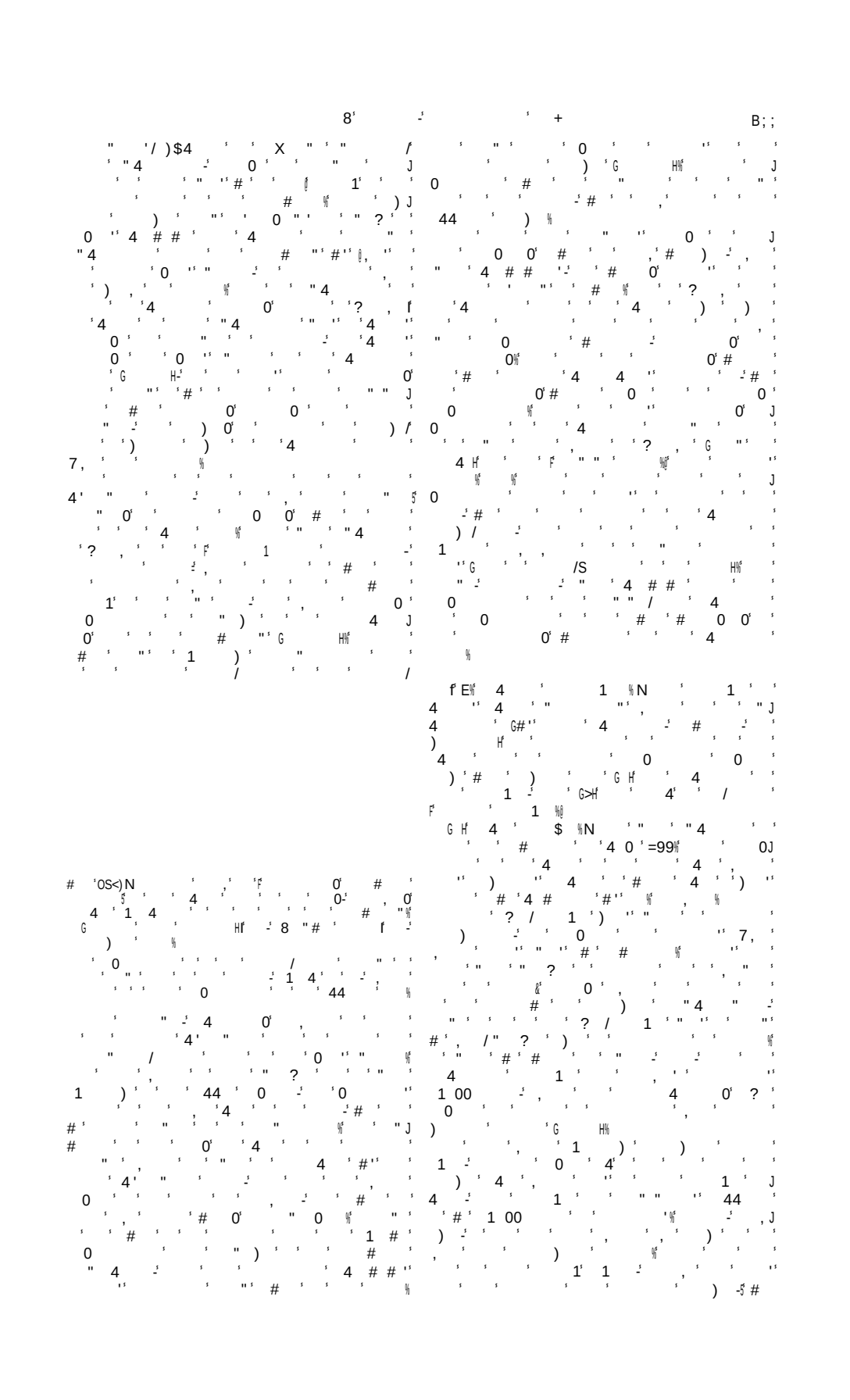


FIG. 151.—Sections of Spinal Cord in lower cervical, mid-dorsal, and mid-lumbar regions (Schäfer). On the right side of each section the conducting tracts are indicated.



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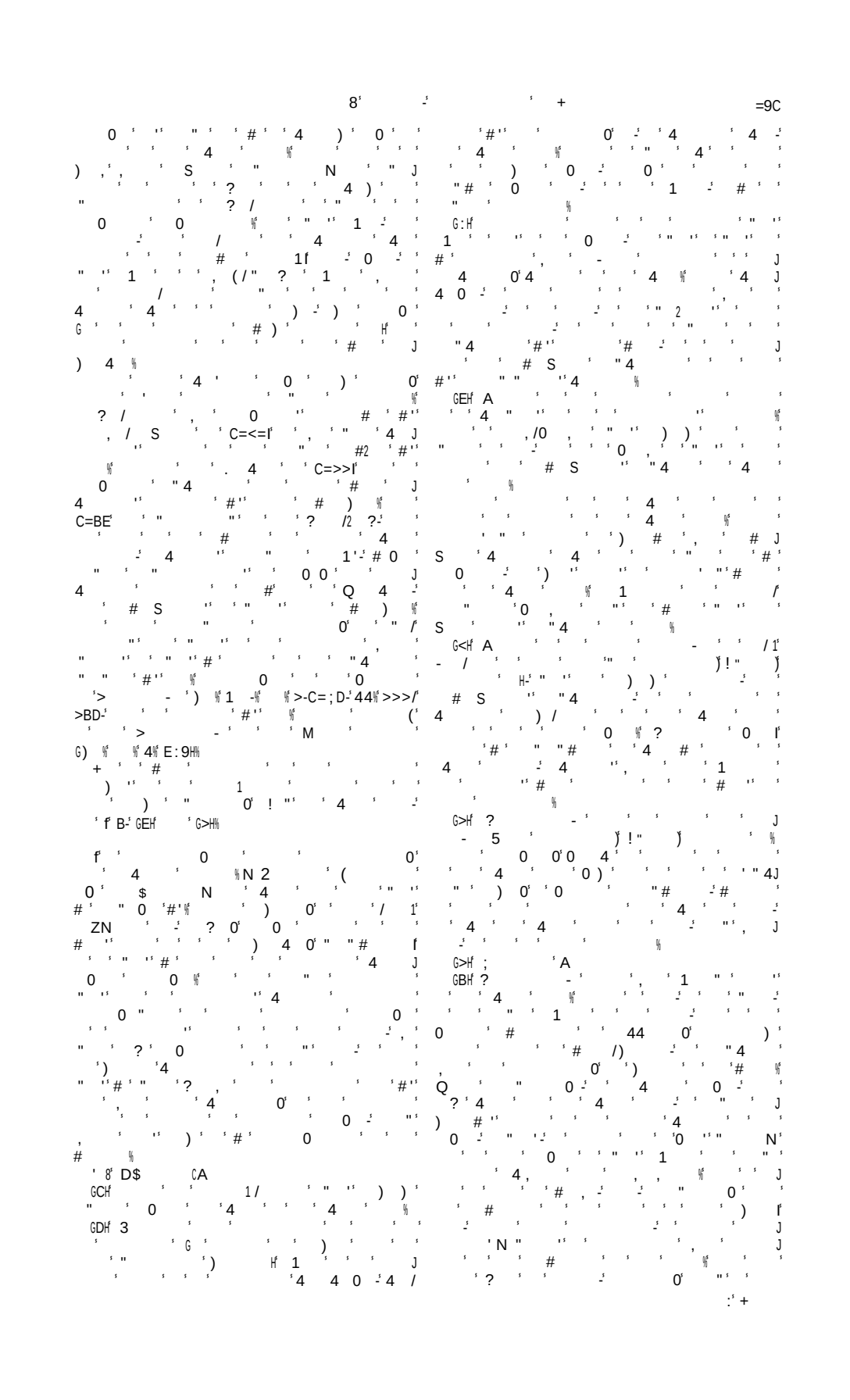

band of degeneration would be found extending downwards from the seat of lesion

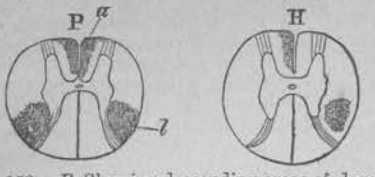

FIG. 153.—*P.* Showing descending areas of degeneration: *a.* in inner part of anterior columns; *l.* in lateral columns (mid-dorsal region). Case of *paraplegia*, from complete transverse softening in upper dorsal region.

H. Showing descending degenerations in case of *right hemiplegia*, from extensive softening of left 'internal capsule.' (Twice natural size.)

Or if, as so frequently happens, we have to do with a total transverse lesion, represented, for instance, by a focus of softening extending through the whole thickness of the cord in the upper dorsal or in some other region (so that the patient suffers from complete paraplegia), we should then find large areas of secondary degeneration in each lateral column below, as well as smaller areas in the inner part of each anterior column (fig. 153, P). The areas in both situations become less extensive as they descend, and gradually wear themselves out in the lower part of the lumbar swelling (see *Med.-Chir. Trans.* vol. l. pl. x.) It was stated by Bouchard, and has been commonly repeated by succeeding writers, that the areas in the anterior columns do not appear beyond the mid-dorsal region; but this mode of termination, as the writer pointed out in 1867, is certainly not invariable.

In such a case as that last cited, namely, one of paraplegia due to a total transverse lesion in the upper dorsal region, there would be found above the seat of lesion certain *ascending degenerations*—the principal of

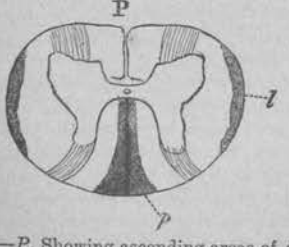

FIG. 154.—*P.* Showing ascending areas of degeneration; *p*, in columns of Goll; and *l*, along outer border of lateral columns, in middle of cervical swelling (corresponding with 'direct cerebellar tract' and the 'tract of Gowers'). Case of *paraplegia*, from complete transverse softening in upper dorsal region.

which would be situated in the posterior columns, though others, smaller and more recently defined, are to be met with in the outer part of the lateral columns (fig. 154).

The ascending degenerations in the posterior columns are often strictly limited to the so-called 'columns of Goll.' Situated on each side of the posterior median fissure, they together constitute a median wedge-shaped patch, whose apex extends forwards to the commissure, and whose base is at the posterior surface of the cord. This band of degeneration reaches upwards to the bulb, where its fibres seem to terminate in the nucleus gracilis.

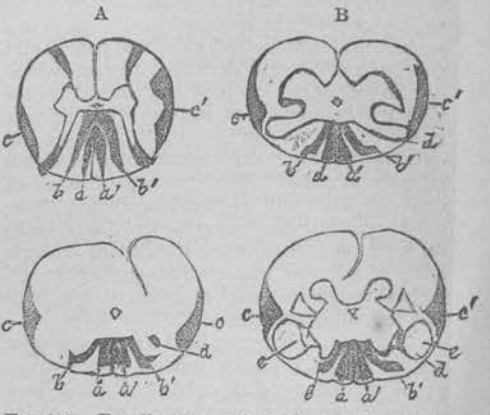

FIG. 155.—Peculiar areas of ascending degeneration, met with in a concussion-lesion of the Spinal Cord.

A, transverse section of the Spinal Cord, near the middle of the cervical region; B, transverse section through the cervical region of the cord, near lower border of medulla; C, section through lower part of medulla oblongata; D, section through Medulla about ¼" below the *Calamus Scriptorius*.

The areas in the posterior columns (*a*, *a'*, *b*, *b'*) have a very peculiar disposition. The areas in the lateral columns in A are very unsymmetrical, that of the right side, anterior to *c'*, represents the lateral sensory tract. Higher sections through the Medulla are represented in *Med.-Chir. Trans.*, 1867, pl. ix.

It seems clear, however, that, under certain conditions, the areas of ascending degeneration in the posterior columns may be differently arranged, and not completely limited to the 'columns of Goll,' since in a case with a lesion of some kind in the mid-cervical region (whose nature is not known, because, unfortunately, this part of the cord was not preserved) the writer long ago found such areas as are represented in fig. 155, in the upper cervical region and in the medulla. The ascending areas of degeneration occupying the superficial portions of the lateral columns were traced by the writer upwards into the restiform bodies. These are areas which we now know to correspond with the subsequently described 'direct cerebellar tract'; whilst the 'tract of Gowers'—corresponding with the part of the areas anterior to *c'* in fig. 155, A and B—which has still more recently been described, also contains

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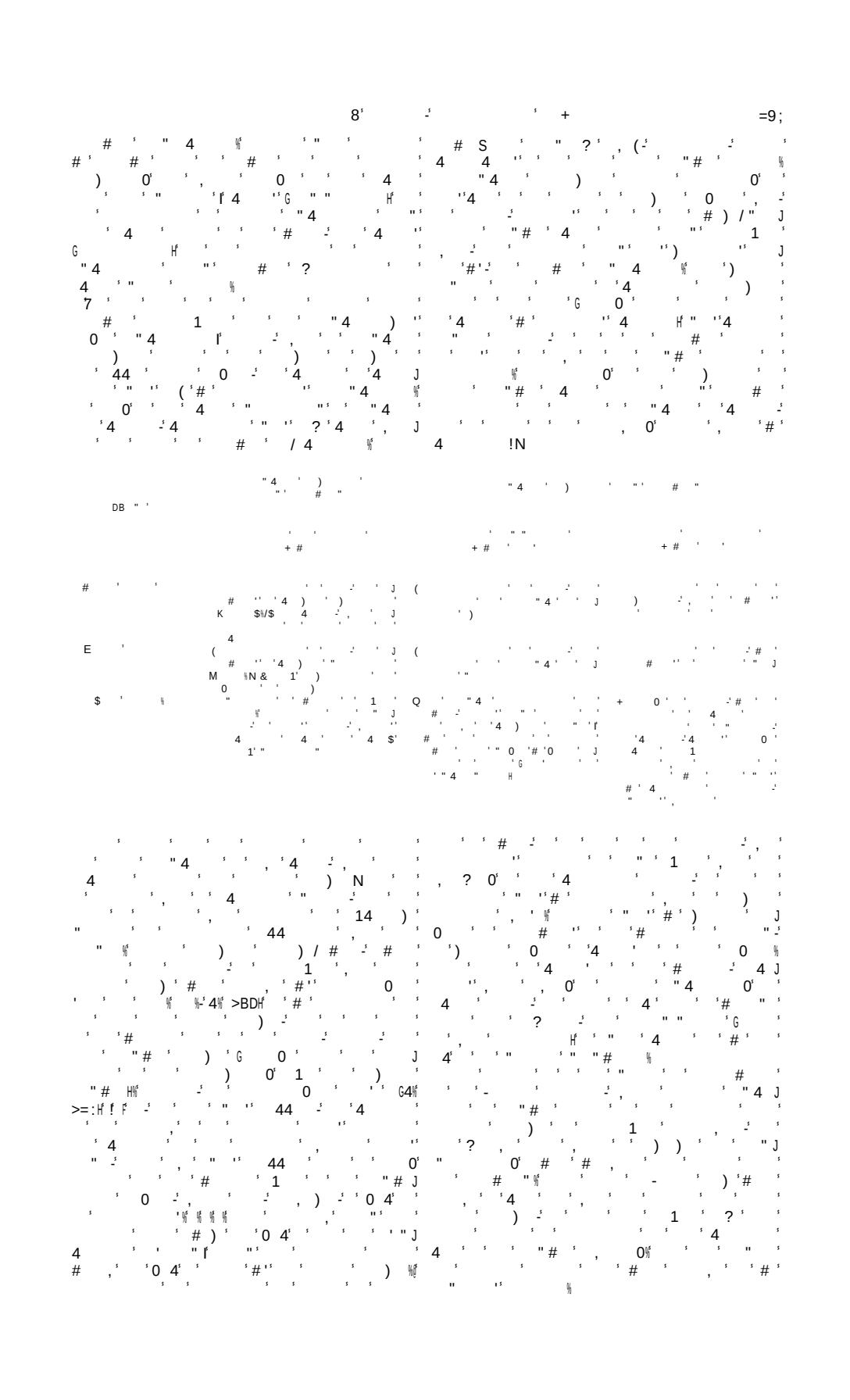

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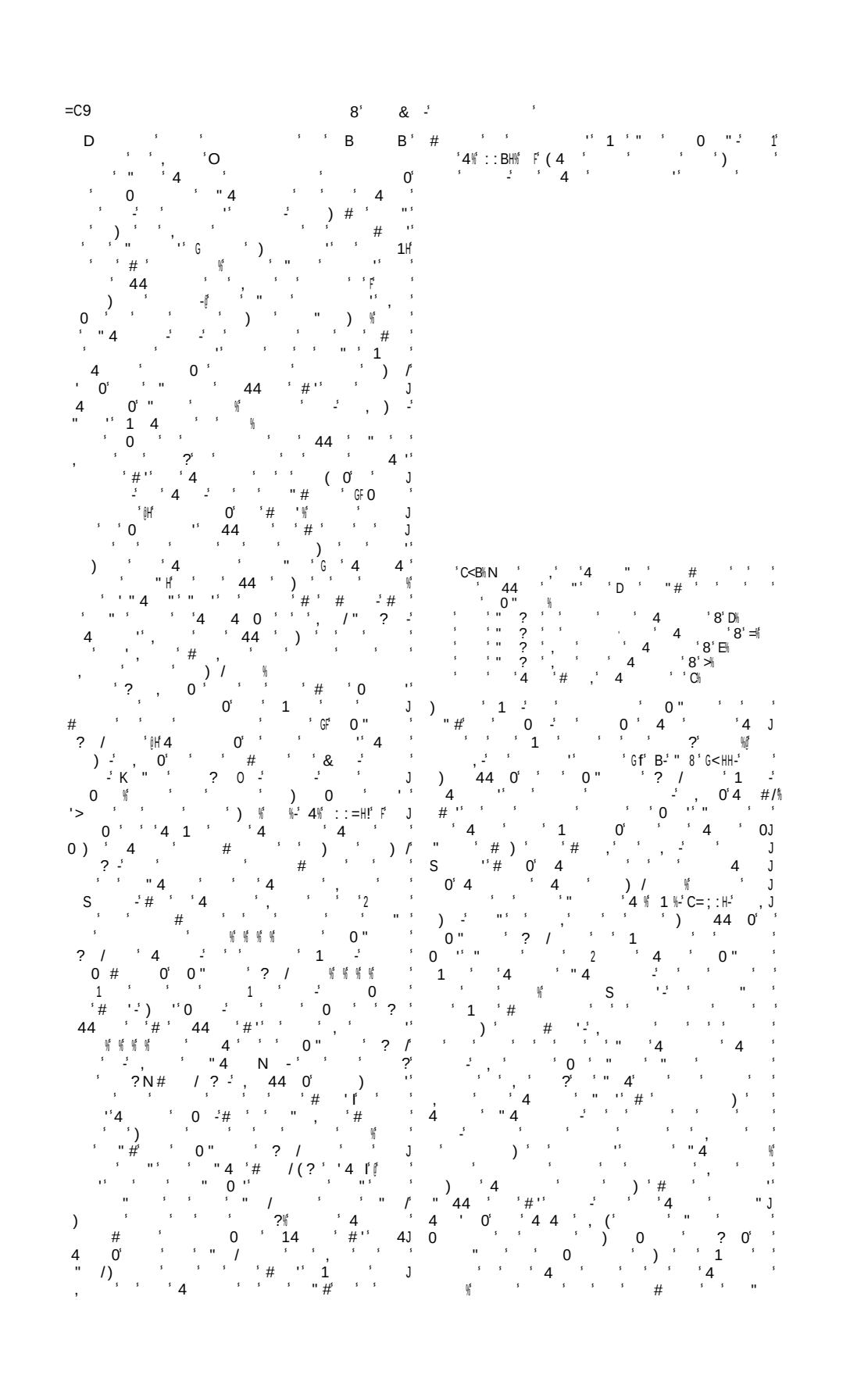

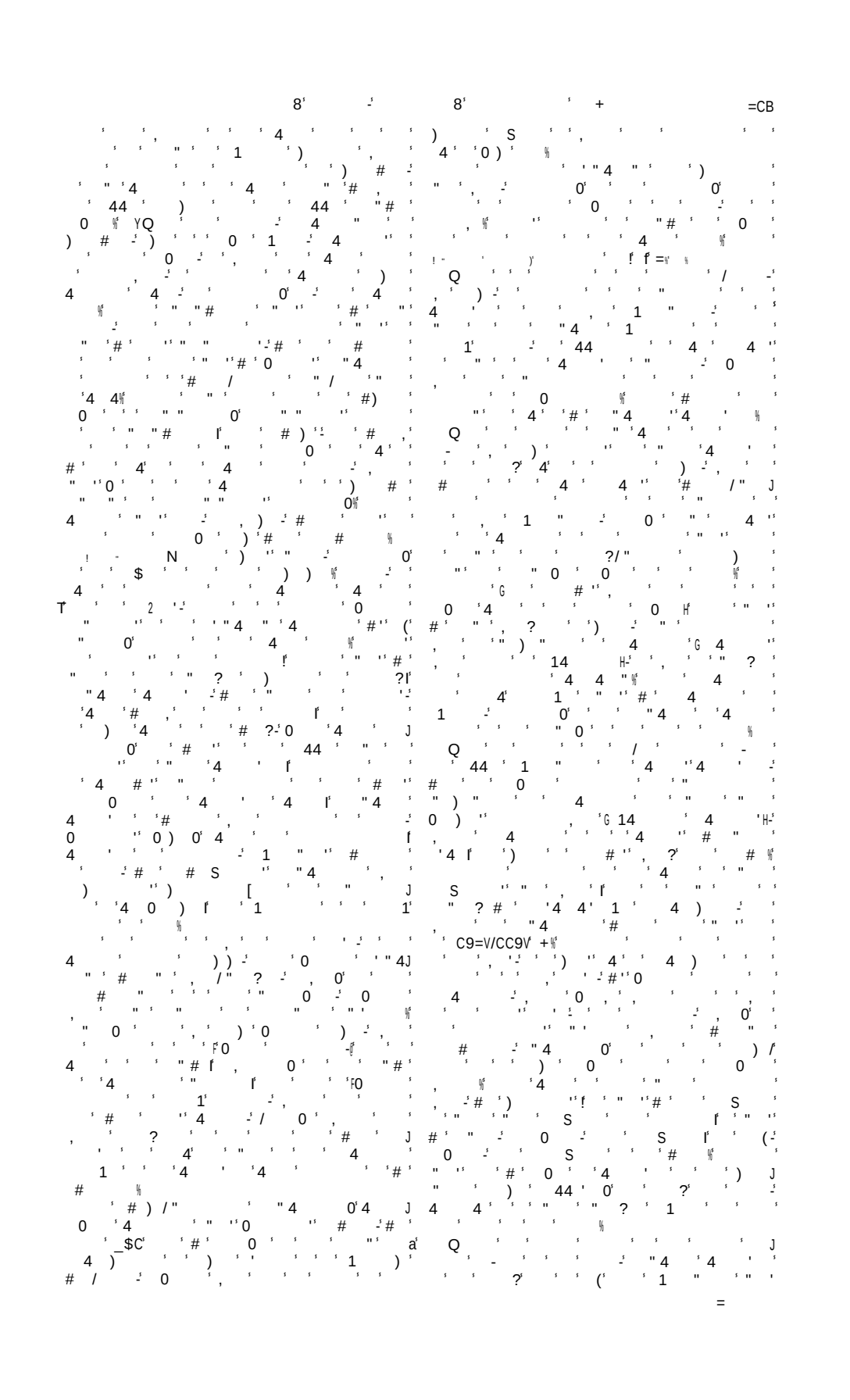

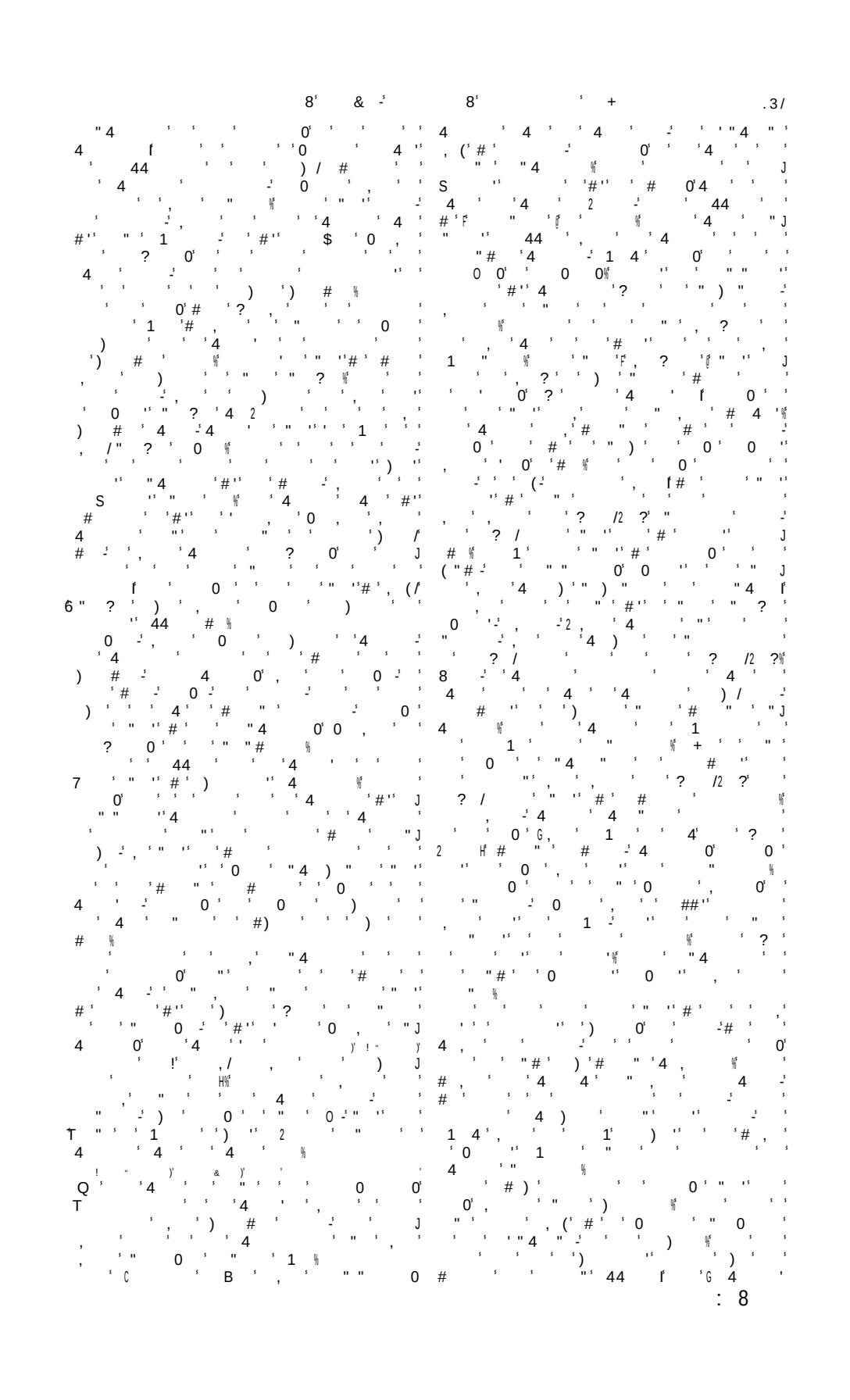

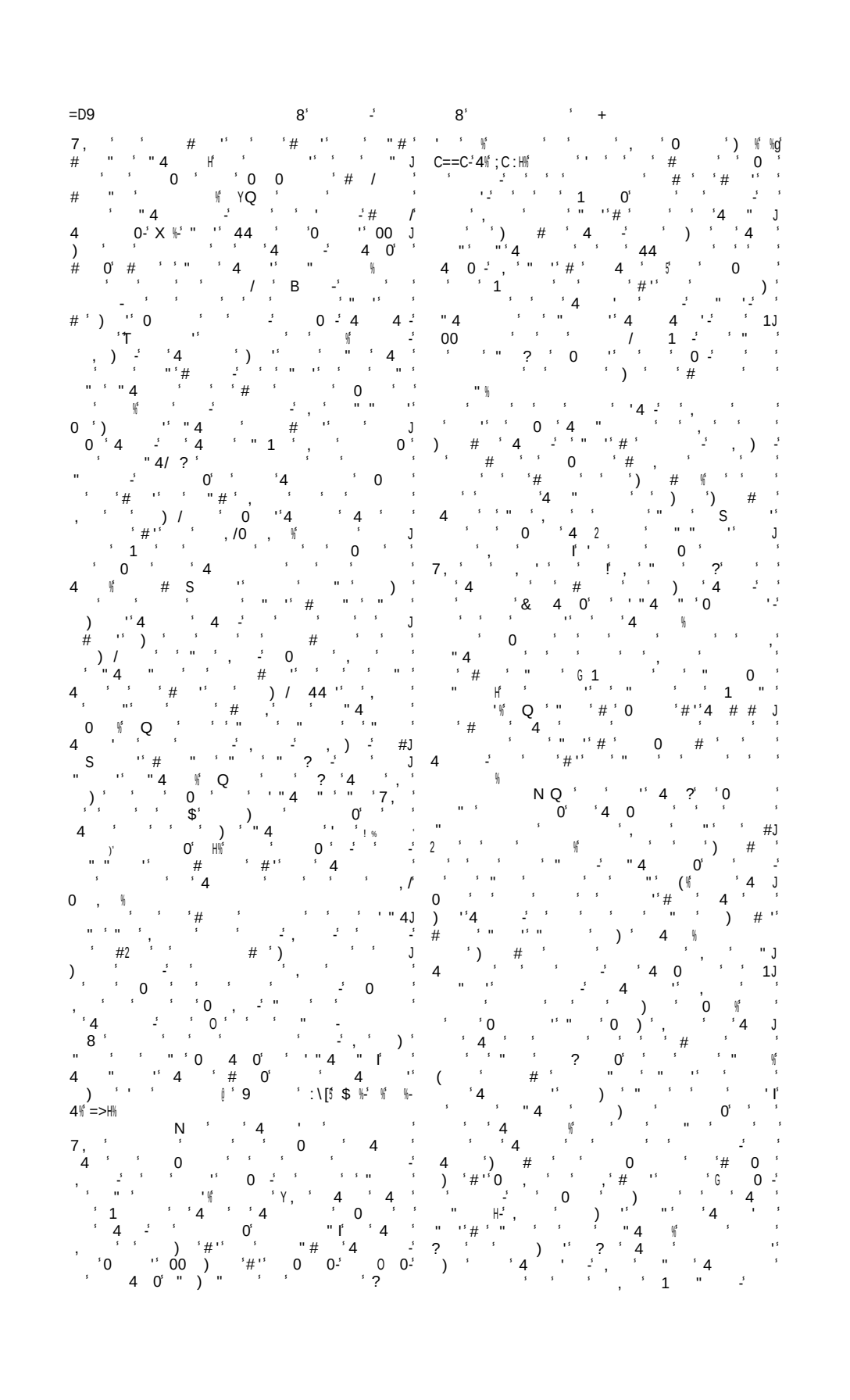

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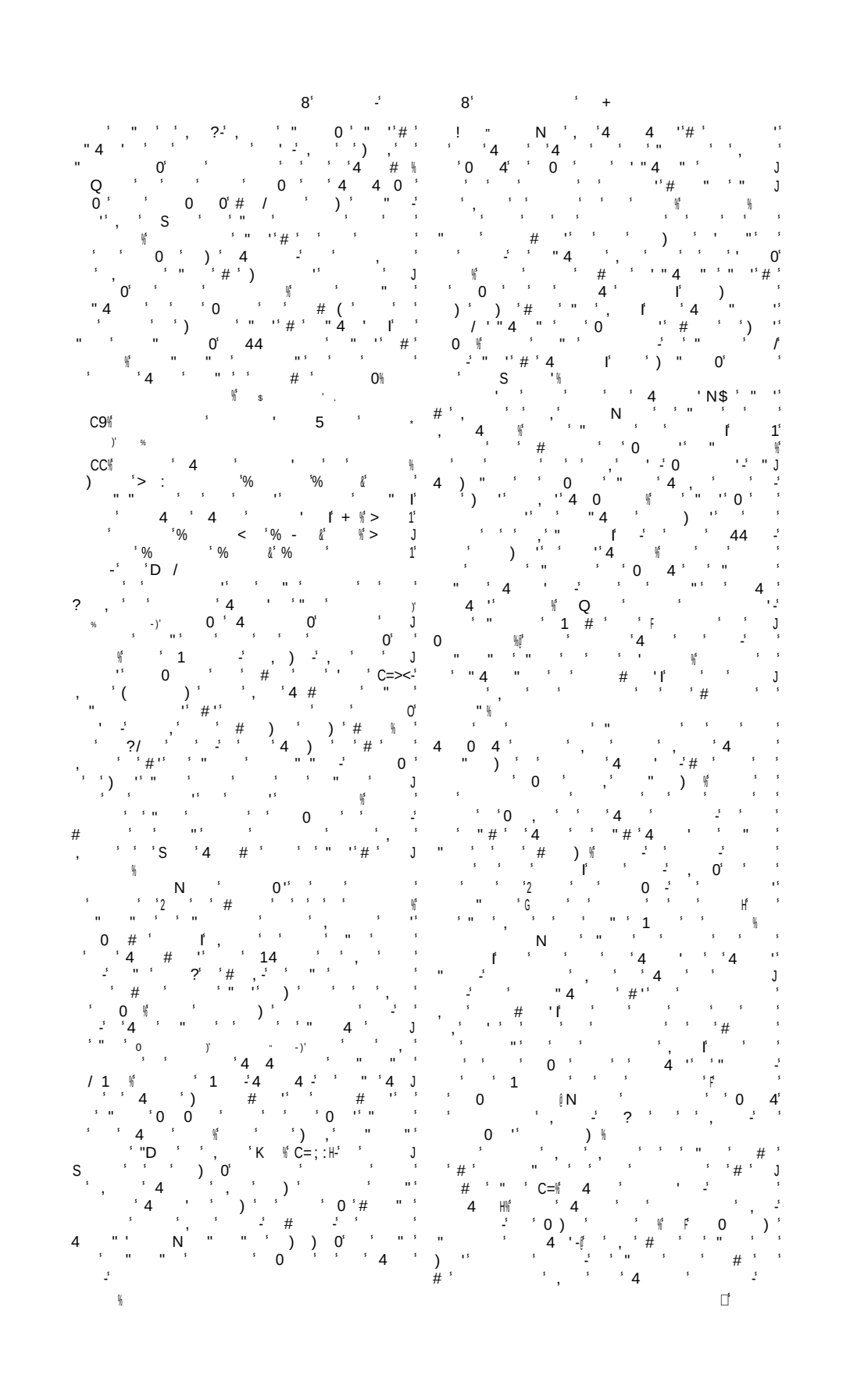

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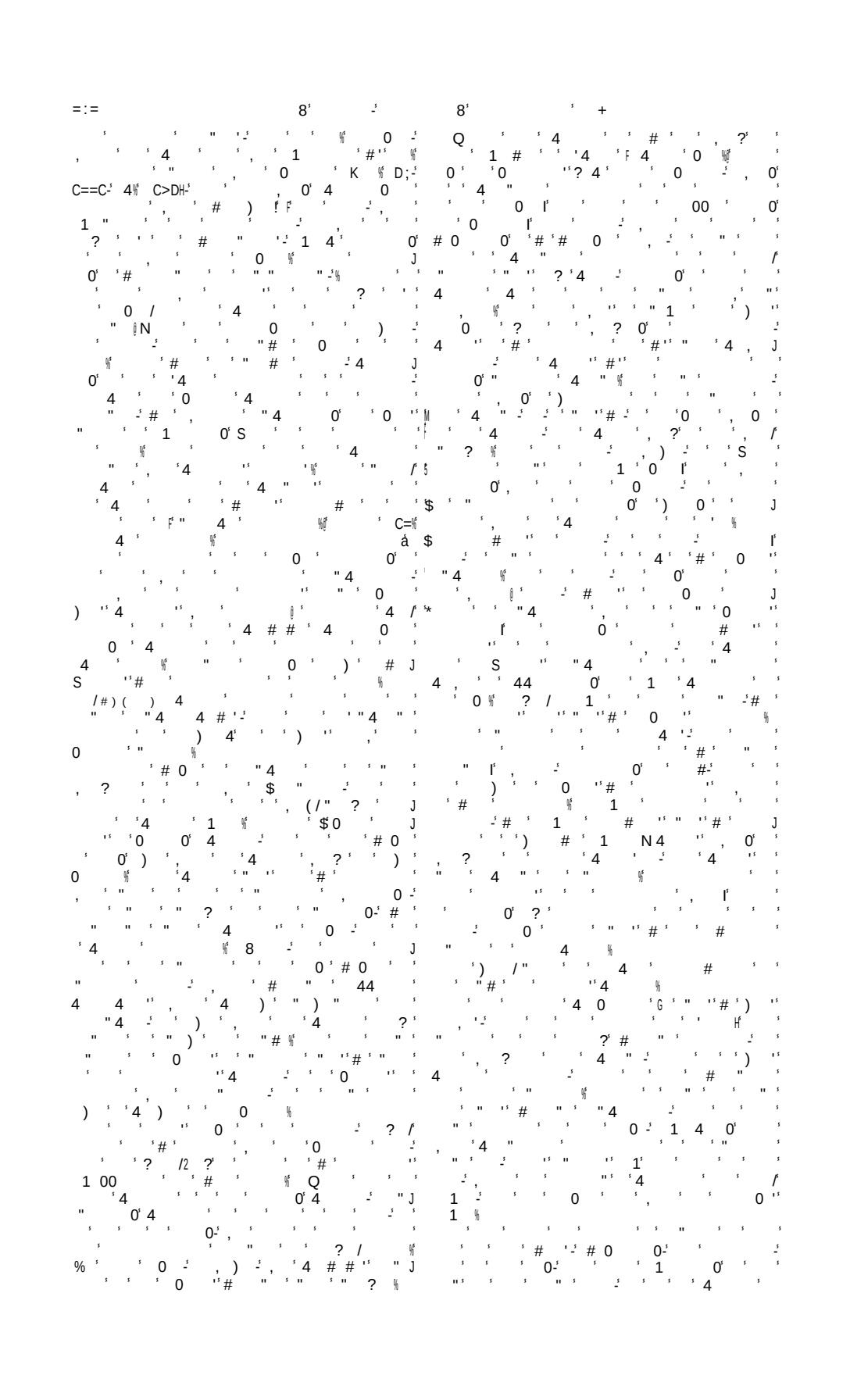

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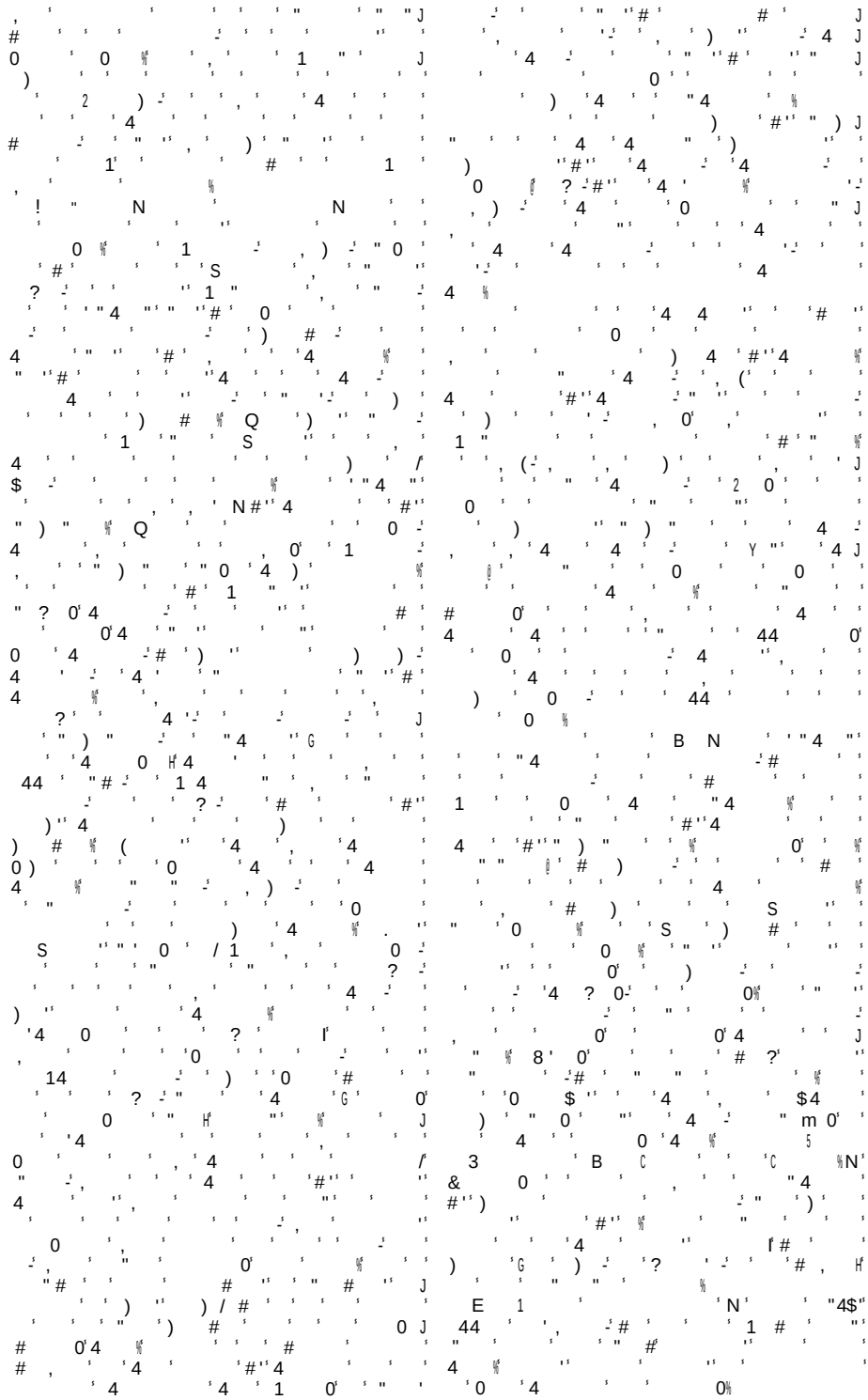

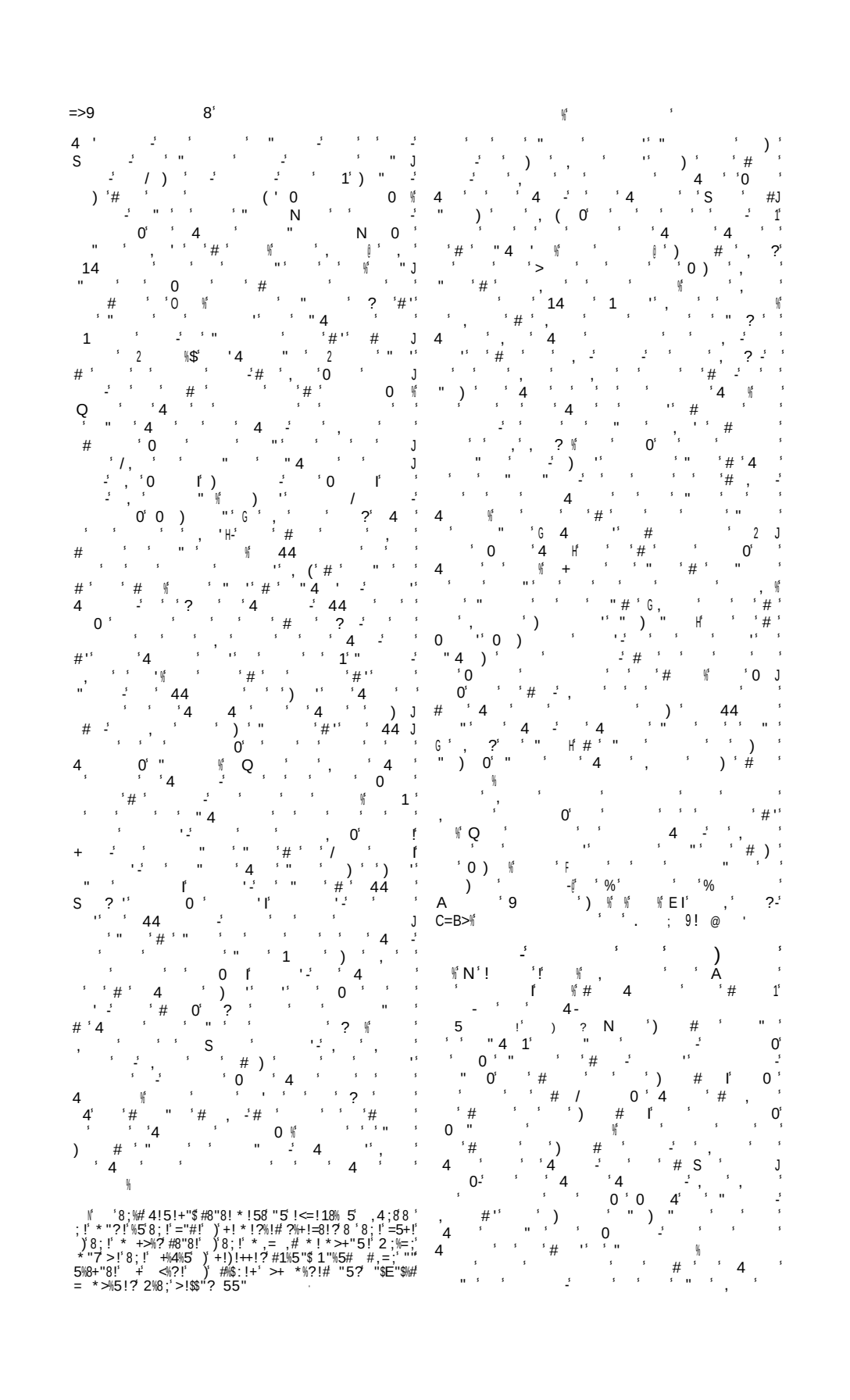

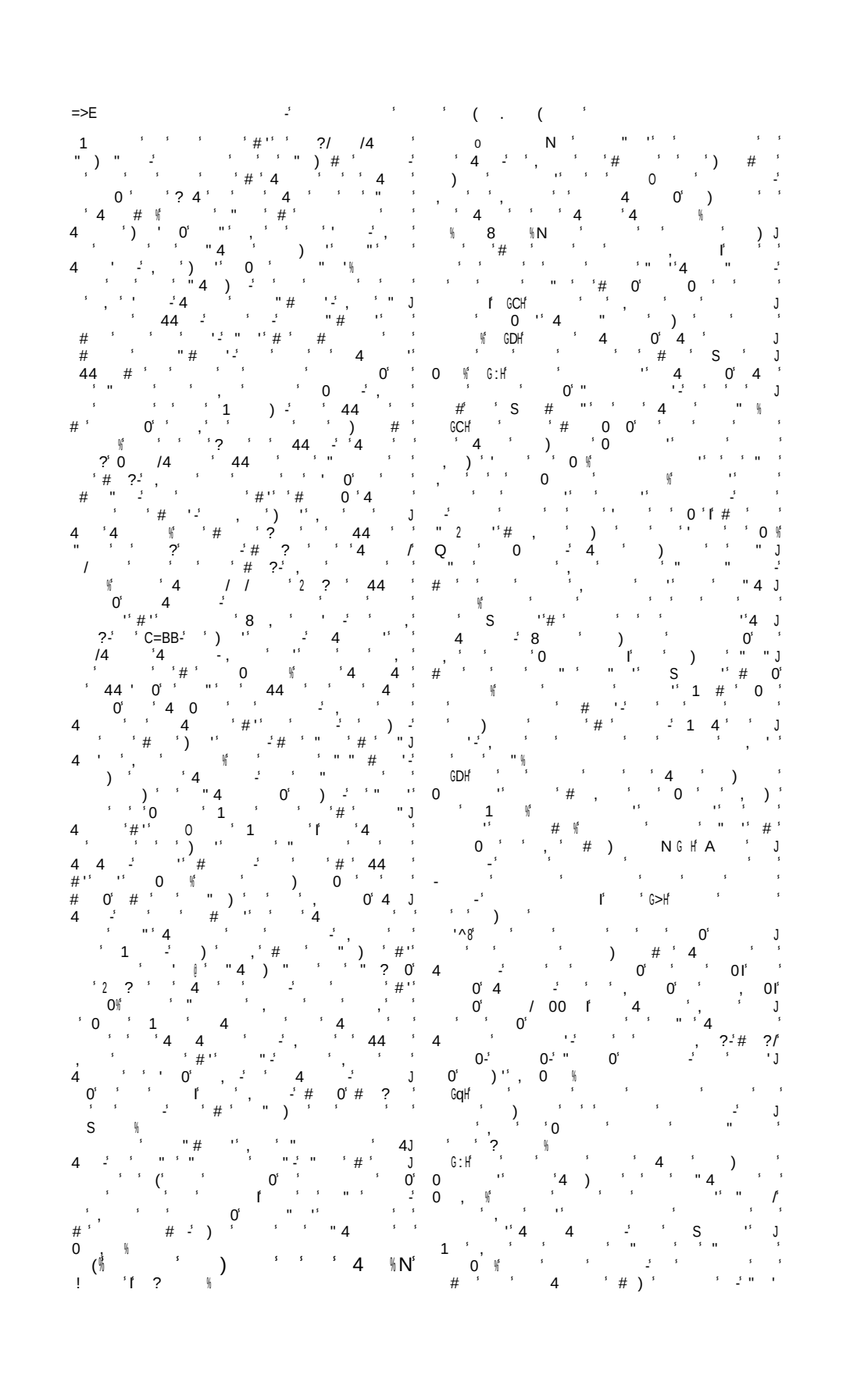

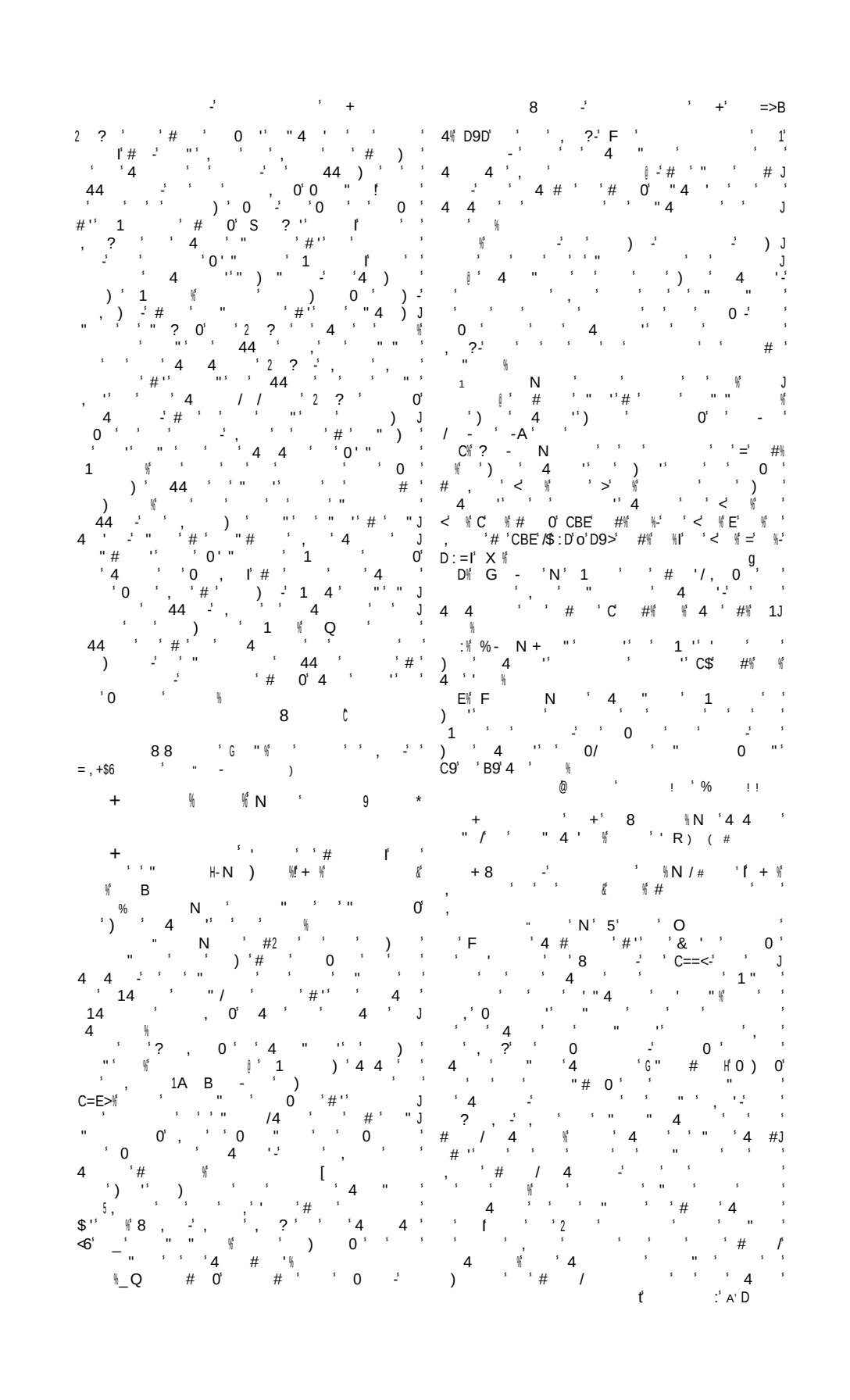

in obtaining sufficiently thin and uniform layers on the two surfaces when the glasses are pressed together. The cover-glasses are now separated by a slight sliding movement, and allowed to dry thoroughly, after which they are passed rapidly face upwards three times through the flame of a spirit-lamp or Bunsen burner to coagulate the albumen. They are then ready for staining. The following reagents are required:—

A. A solution of fuchsine. Several different formulæ have been proposed, but either of the two following may be adopted:—

(1) Ehrlich's solution, consisting of 11 c.c. of a saturated alcoholic solution of fuchsine added to 100 c.c. of a saturated watery solution of aniline oil. This fluid is very unstable, and should be made freshly each time it is required. Small quantities may be prepared by pouring five or six drops of the alcoholic solution of fuchsine into a watch-glass full of aniline water.

(2) Ziehl's solution, or carbol fuchsine, consisting of 10 c.c. of a saturated alcoholic solution of fuchsine added to 90 c.c. of a 5 per cent. watery solution of carbolic acid. This solution has the advantage of being much more stable than the first, and may be preserved for several months.

B. A 25 per cent. solution of sulphuric acid.

C. A concentrated watery solution of methylene blue.

The staining fluids must be filtered each time they are used.

The cover-glasses on which the sputum has been dried are placed in some of the fuchsine solution (A) in a watch-glass or glass capsule, and the fluid is heated cautiously over a spirit-lamp or on a sand bath until bubbles begin to rise. The solution is then allowed to cool for two or three minutes, after which the cover-glasses are removed with forceps and dipped into some of the acid solution (B) for two or three seconds, and then quickly washed for about ten seconds in a fine stream of water flowing from a tap. The preparation has a deep red colour when removed from the fuchsine, but assumes a yellowish-grey appearance in the acid. When subsequently washed in water, the specimen again turns red. Next the cover-glass is stained with the blue dye (C) for about a minute, and again washed for five or six seconds in a stream of water. The excess of water is then drained away, and the cover-glass is allowed to dry. The process may be shortened by drying the cover-glass cautiously between two pieces of filter-paper. When the specimen is thoroughly dry, it is mounted in a drop of Canada balsam dissolved in benzol or xylol.

For the recognition of the tubercle bacilli, a magnifying power of 250 to 300 is sufficient in most cases, if the illumination be brilliant. Abbé's sub-stage condenser greatly facilitates the detection of the bacilli; and in all doubtful cases, where the microbes are scanty, the combination of Abbé's condenser with a one-twelfth oil-immersion lens is indispensable. With the method of staining above described, the bacilli appear as delicate crimson rods, in length from one-quarter to one-half the diameter of a human red blood-corpuscle. The rods may present a uniform bright red appearance, the staining may be unequal, or the microbes may present a beaded appearance resembling a string of red granules. The last result of staining has been attributed to the presence of spores in the bacillus. No clinical importance can be attributed to these morphological differences. Various other bacilli and micrococci contained in the sputum, as well as the nuclei of cells and filaments of mucin, take the blue stain, contrasting sharply with the red tubercle bacilli.

FIG. 158.—Tubercle Bacilli in Sputum. × 550.

The bacilli are seen as dark rods, lying amidst threads of mucus and a few pus-corpuscles.

The clinical recognition of the bacillus is based on the staining reactions involved in the foregoing process devised by Ehrlich. The bacillus of tuberculosis is distinguished from all others, with the exception of the leprosy bacillus, by the fact that it retains the stain of certain aniline dyes when exposed to the action of strong mineral acids, other bacilli becoming decolorised by this process.

The following is Ehrlich's explanation of the results of his method:—

In order to stain the tubercle bacillus successfully, a combination of a salt of aniline with aniline itself, or with phenol, is required. The double compound thus formed is an oily, comparatively insoluble, substance of a brilliant colour, which becomes deposited in the protoplasm of bacilli and cells generally. The tubercle bacillus takes up watery solutions of the aniline dyes with great difficulty, but is readily stained when certain of these dyes are combined with aniline or phenol. This peculiarity probably depends on the existence of a special sheath enclosing the bacillus. The sheath resists the passage of watery and

and examined with the microscope in the usual way. A magnifying power of 90 to 100 diameters is sufficient in most cases; but when the fibres are isolated or much broken up, a higher power may be required. In the latter case, difficulties are apt to arise from the fact that the sputum commonly contains adventitious fibres closely resembling elastic tissue. In some cases the curled-up ends and branching fibres may serve to distinguish the elastic tissue of the lung; but unless some trace of the characteristic alveolar arrangement be recognisable, it is unwise to hazard a positive diagnosis. *See* MICROSCOPE IN MEDICINE.

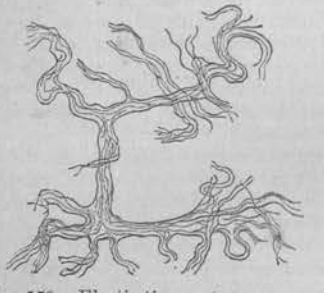

FIG. 159.—Elastic tissue of the lung in Sputum. ×550.

SIGNIFICANCE.—The discovery of elastic tissue in the expectoration may be regarded as definite evidence of destructive disease of some portion of the respiratory tract. With rare exceptions, the elastic fibres come from the lung, though at times they may be derived from the larynx or bronchi, in which case no alveolar grouping will be found. Tuberculosis, by far the commonest ulcerative disease of the lung, may generally be suspected when elastic tissue is found in the sputum; but in non-tubercular destructive affections the same discovery may be made. Hence elastic fibres do not possess the pathognomonic significance of the tubercle bacilli. In acutely progressing excavation, large groups of alveoli are often expectorated; whereas in cases of chronic disease the fibres are usually more isolated, and are not uncommonly encrusted with lime salts.

In the sputum of pulmonary gangrene the elastic fibres are generally scanty or ill-defined, and sometimes cannot be recognised at all. It has been suggested that this is due to the presence of a ferment in the gangrenous secretion, which dissolves the lung-tissue.

3. **Curschmann's Spirals.** — In the sputum expelled towards the close of an asthmatic attack, small gelatinous sago-like lumps of mucus are generally present. If these masses be gently pressed out between a cover-glass and a glass slide, certain spiral structures may commonly be recognised. The spirals vary much in size, often being visible to the naked eye, whereas at other times they can only be discovered with the help of the microscope. These structures consist of gelatinous threads of a mucoid substance, coiled in the form of a corkscrew. In many cases a central bright wavy or twisted thread occupies the hollow of the coil. v. Jaksch believes the central fibre to be chemically allied to fibrin, the spiral coil being composed of mucin.

SIGNIFICANCE.—These spirals are to be regarded as casts of the bronchioles. Curschmann considers that they are the result of an exudative bronchiolitis, and are causally related to the paroxysms of asthma. The spirals are not pathognomonic of asthma, as they are occasionally found in the sputum of bronchitis and croupous pneumonia. But, as v. Jaksch suggests, their presence in a case of asthma of doubtful nature would stamp the bronchial nature of the attack. Charcot-Leyden crystals (*see* MICROSCOPE IN MEDICINE) are often found adhering to the spirals, and sometimes seem to develop after the sputum has been allowed to stand for some hours. v. Jaksch believes that the crystals are products of chemical decomposition of mucin. PERCY KIDD.

SQUAMÆ (*squama*, a scale).—Scales. A synonym for scaly diseases of the skin. *See* PITYRIASIS RUBRA.

SQUINTING. — A popular name for strabismus. *See* STRABISMUS.

STADIUM (Lat., a stage).—A period or stage in a disease, as in fever; for example, *stadium incrementi*, *stadium convalescentiæ*.

STAGNATION OF BLOOD.—Local arrest of the circulation. *See* CIRCULATION, Disorders of; and INFLAMMATION.

STAINS.—This word, as applied to the skin, is synonymous with 'maculæ.' *See* MACULÆ.

STAMMERING.—SYNON.: Fr. *Bégaiement*; Ger. *Stottern*.

DEFINITION.—Under the head of stammering, in its broadest sense, are included many different forms of defective articulation, such as the inability, congenital or acquired, to pronounce certain letters or certain combinations of letters, the tendency to hesitate or stumble in utterance or to transpose letters or syllables, and the habit of interjecting meaningless sounds or words into the pauses which occur in the course of continuous speech. But the term is generally used, at any rate in English, as synonymous with *stuttering*, to imply a spasmodic affection of the organs concerned in speech, in virtue of which the enunciation of words becomes suddenly checked, and a painful pause ensues, not infrequently marked by a

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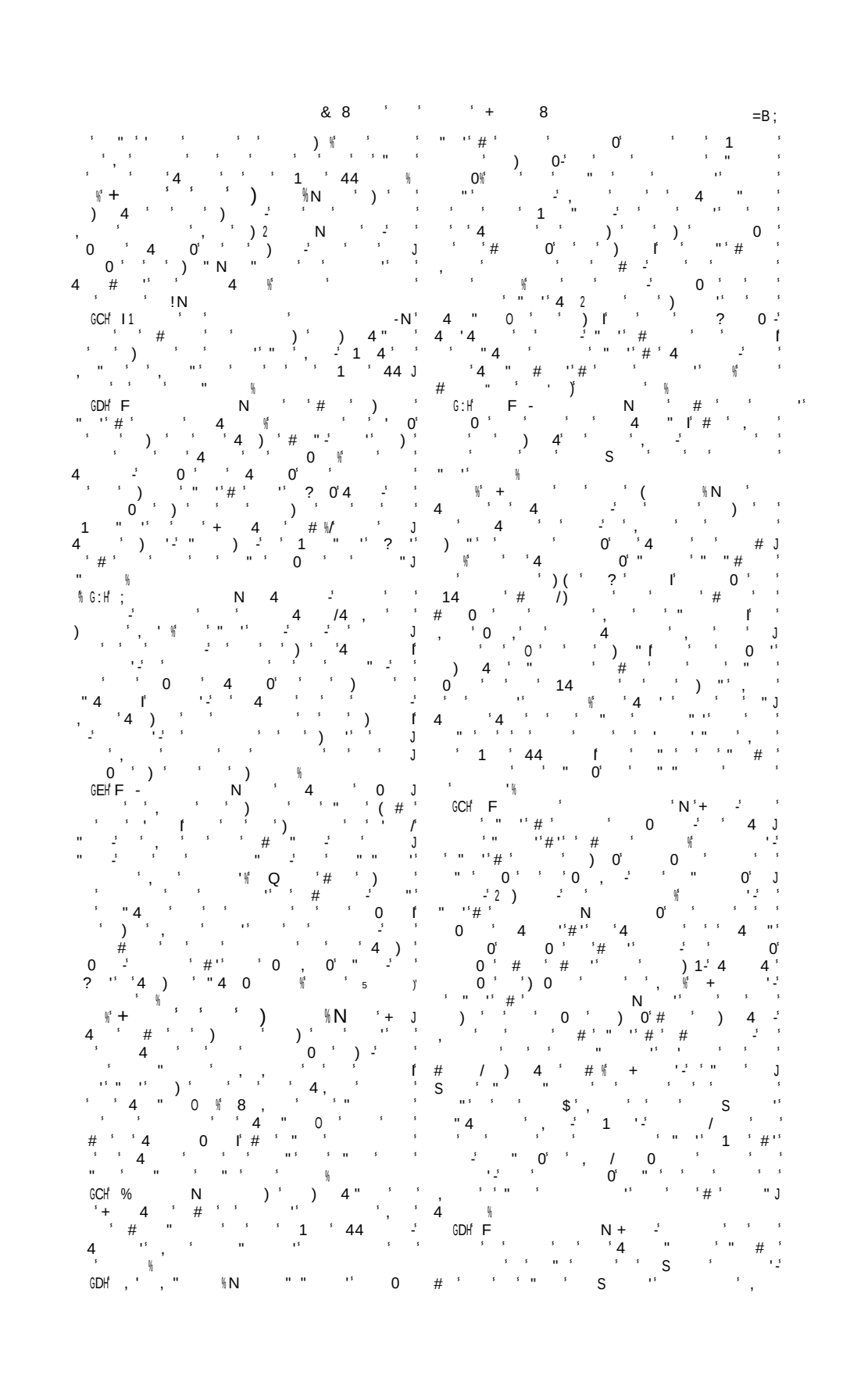

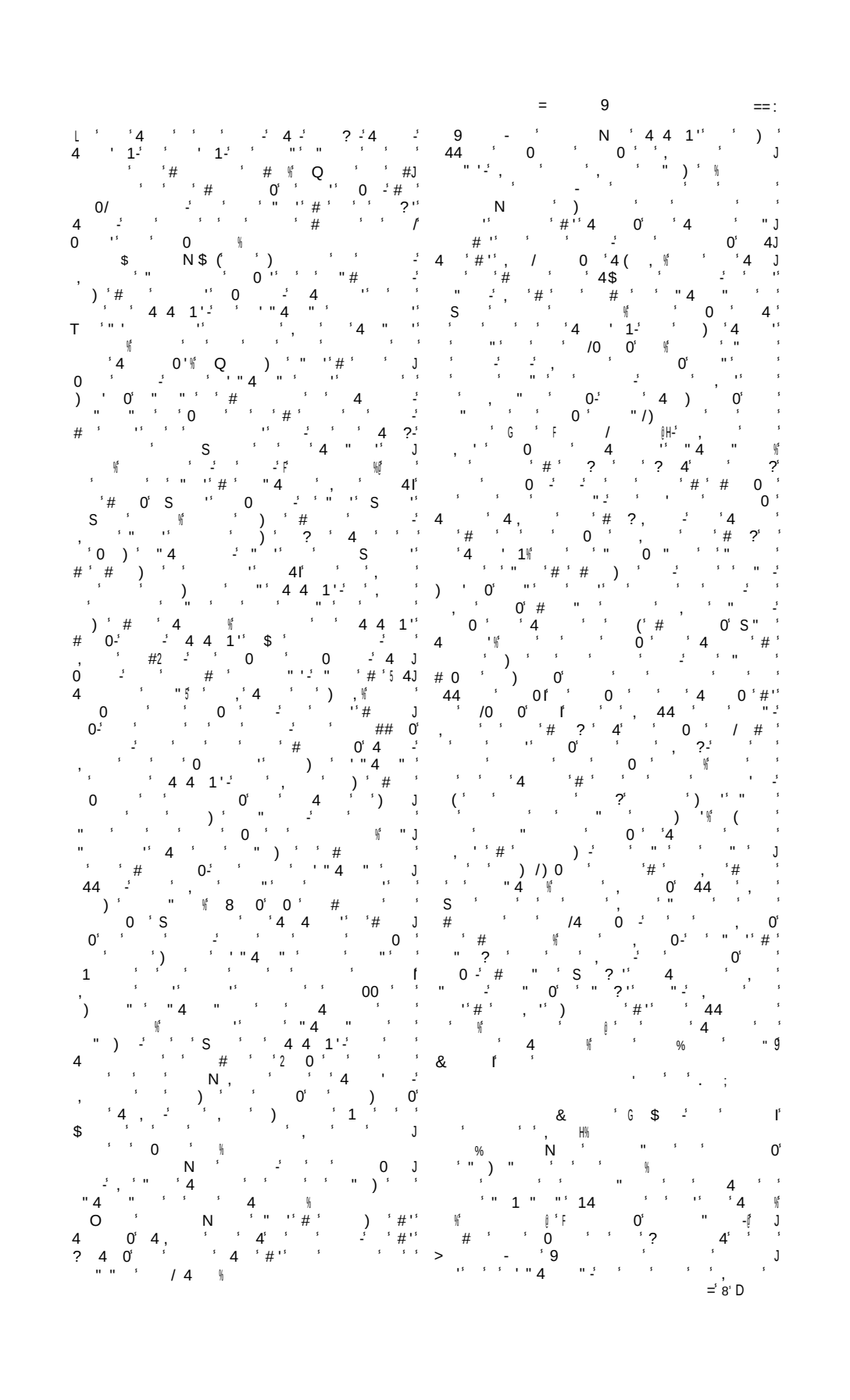

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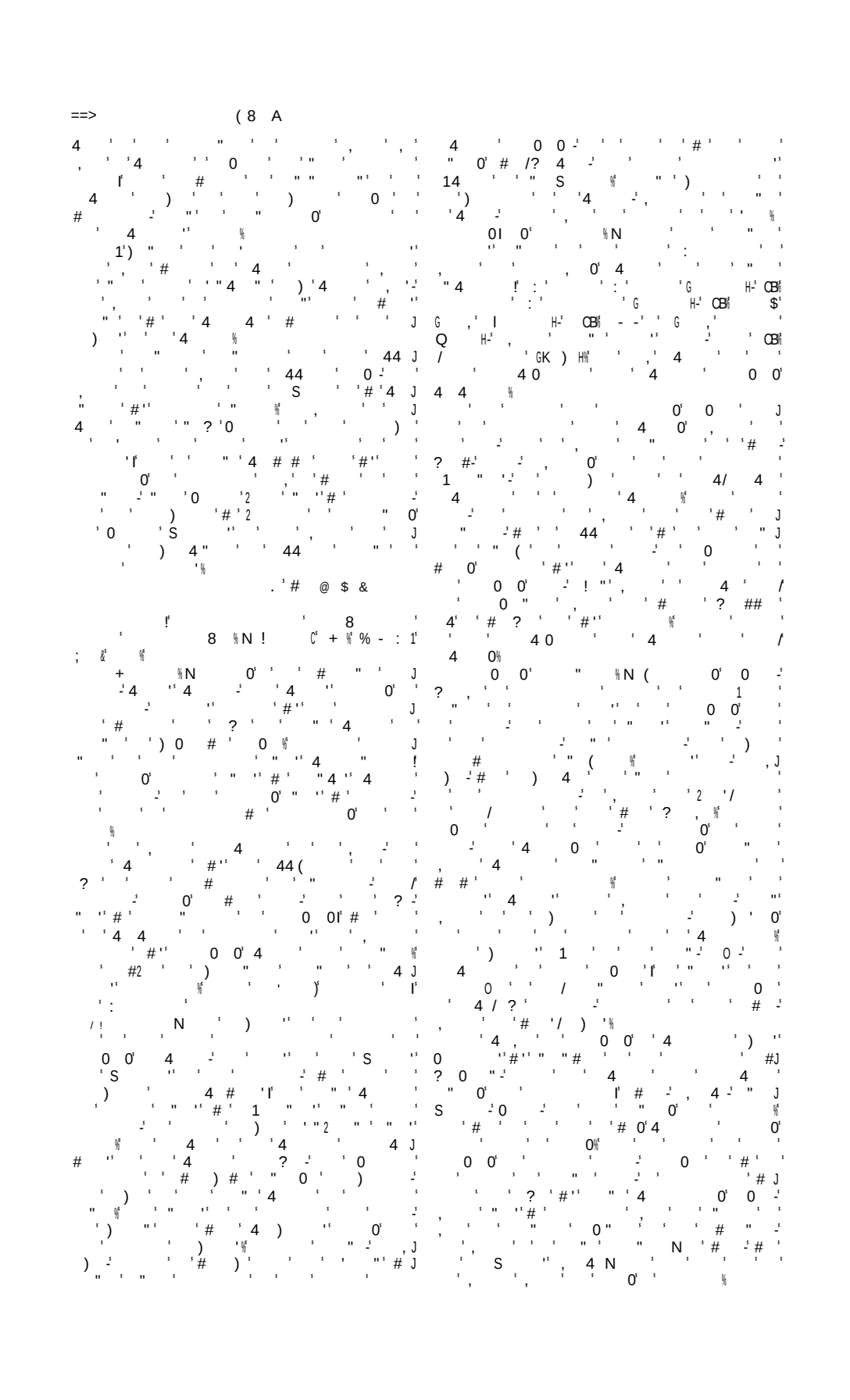

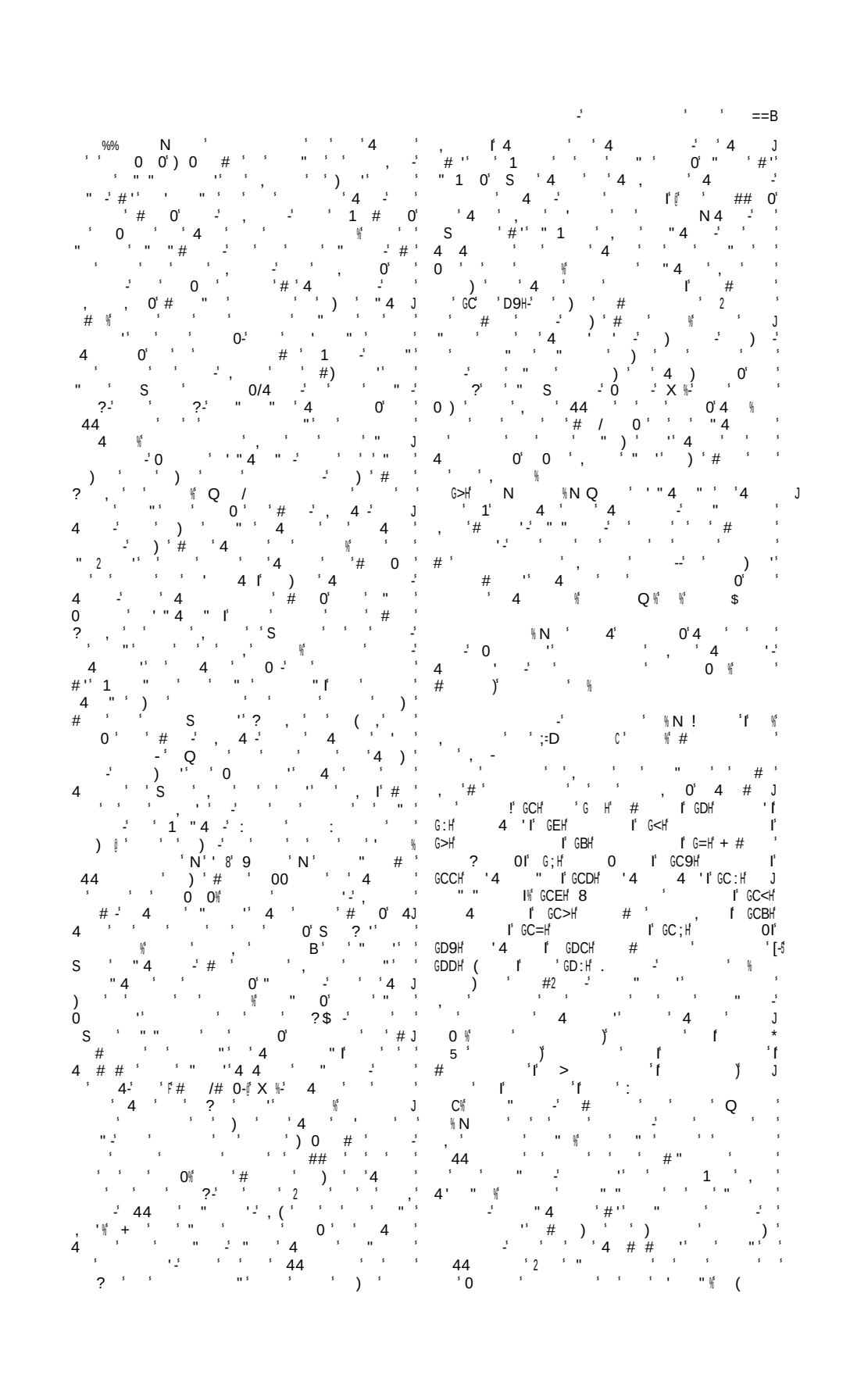

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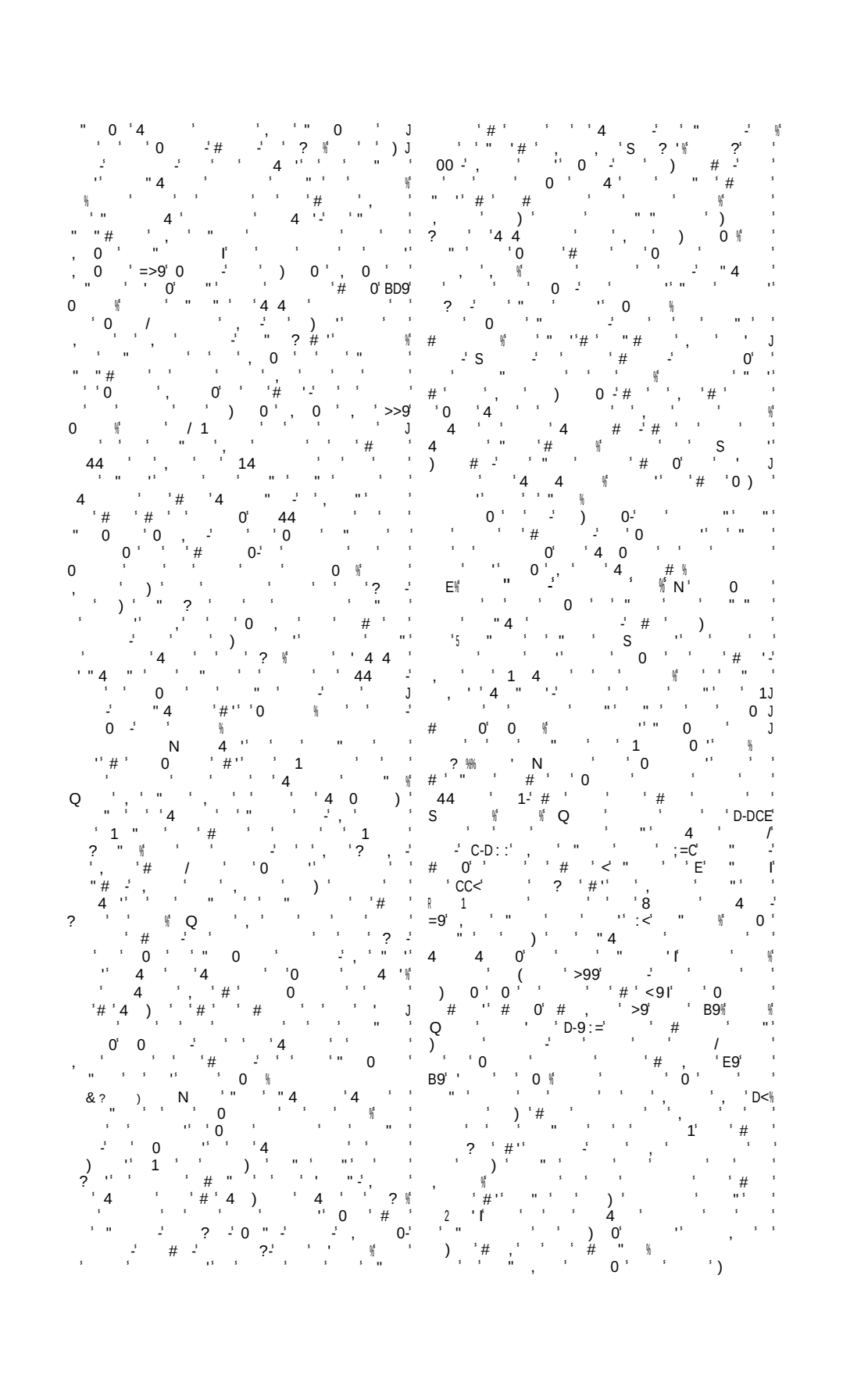

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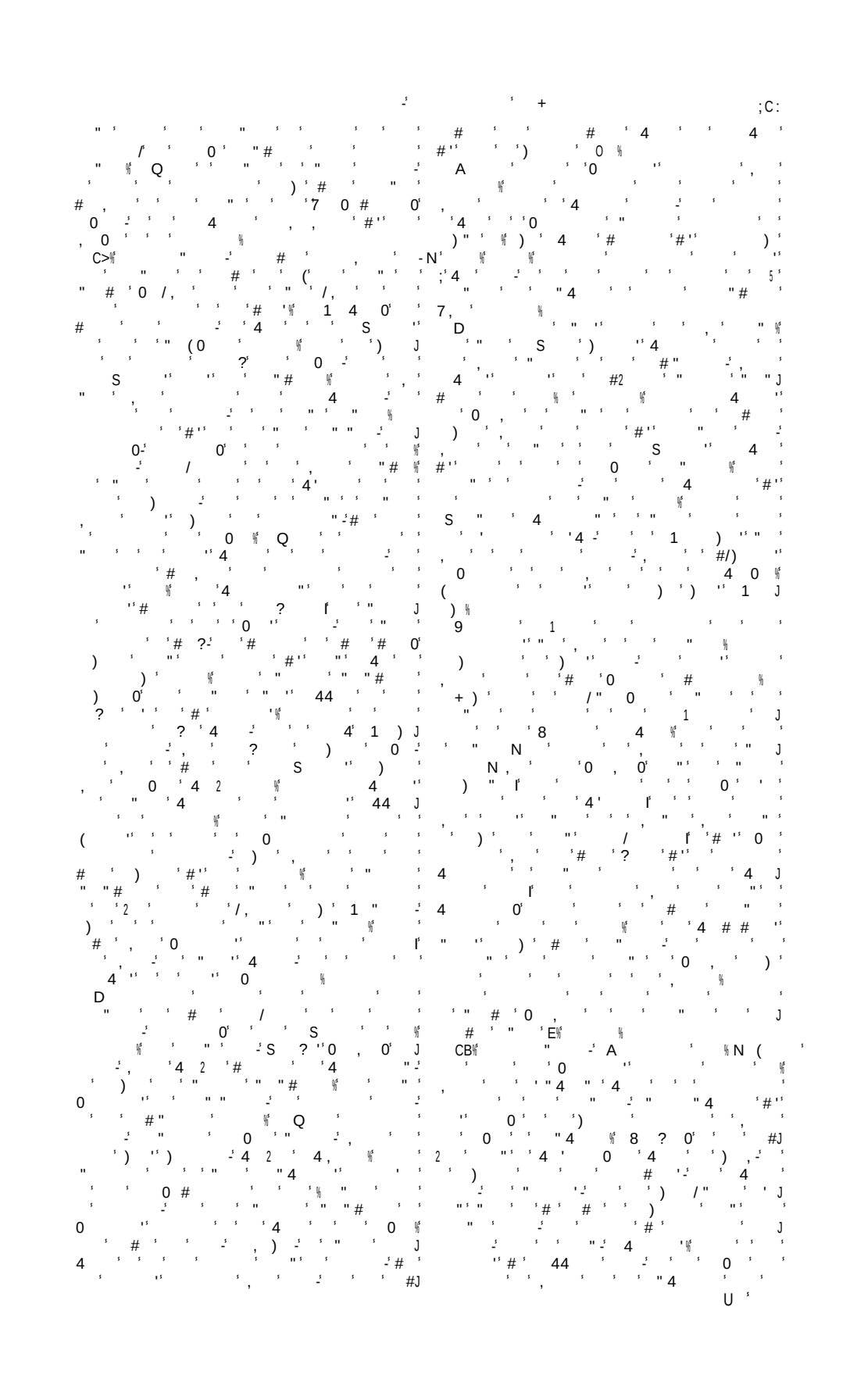

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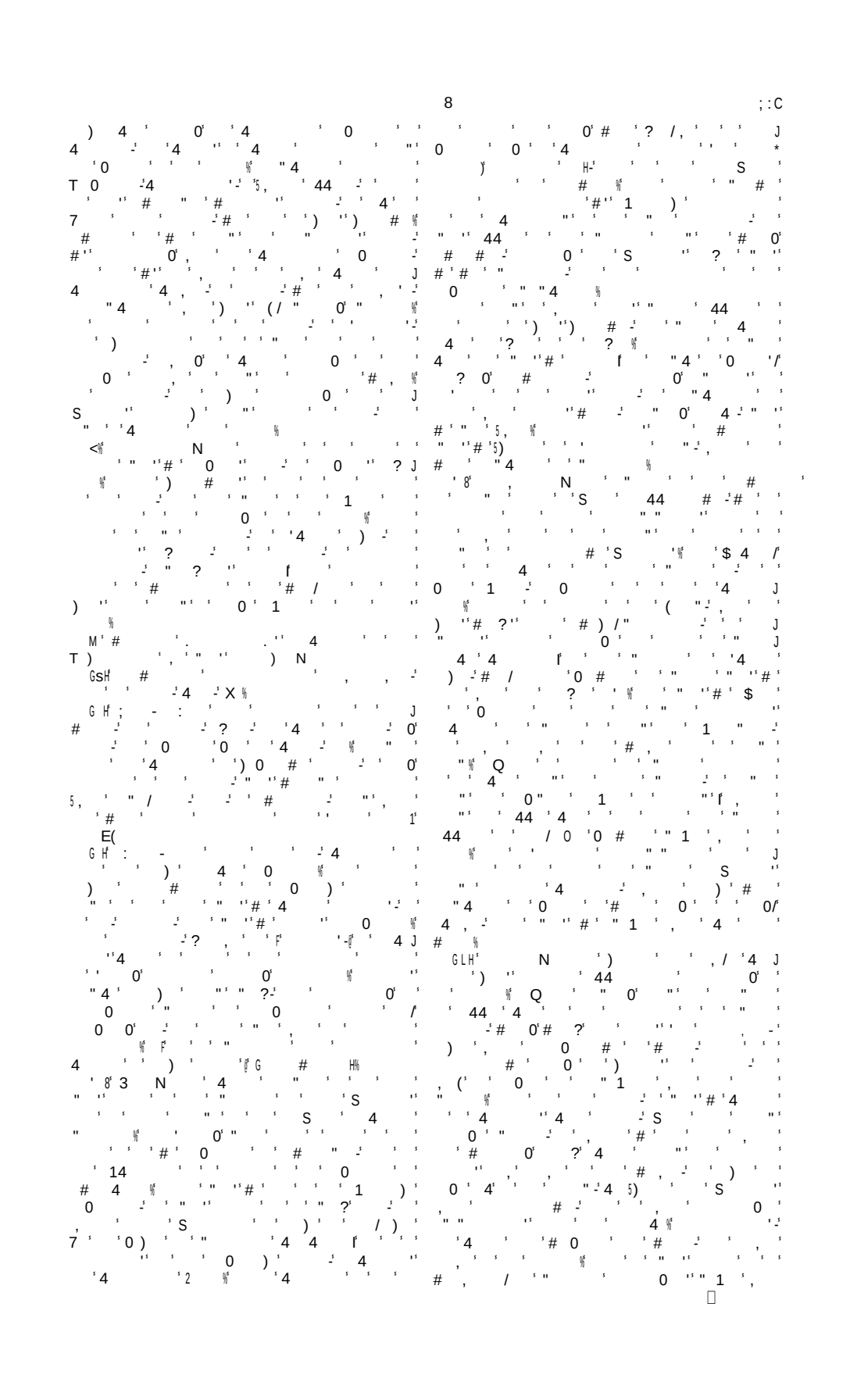

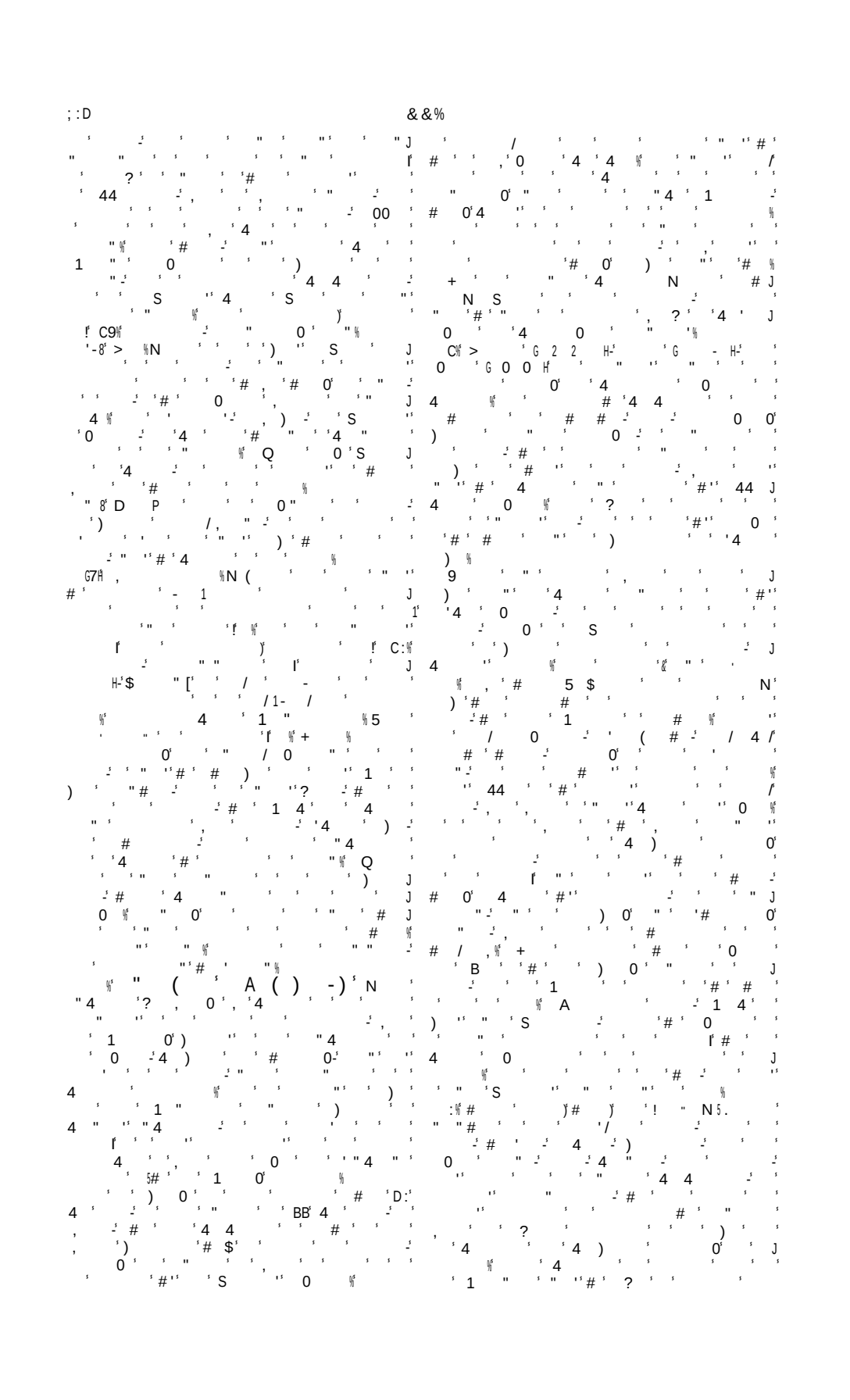

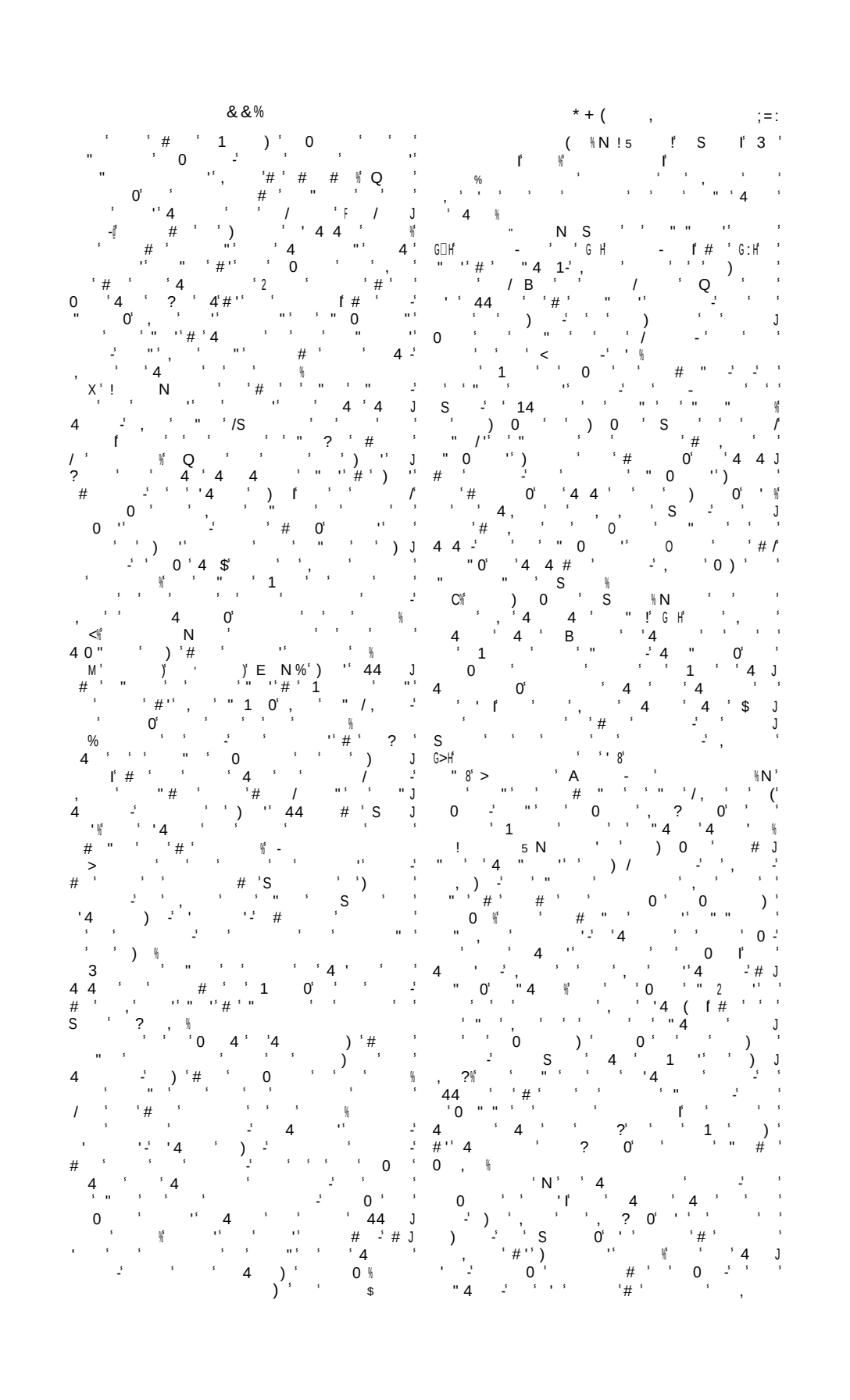

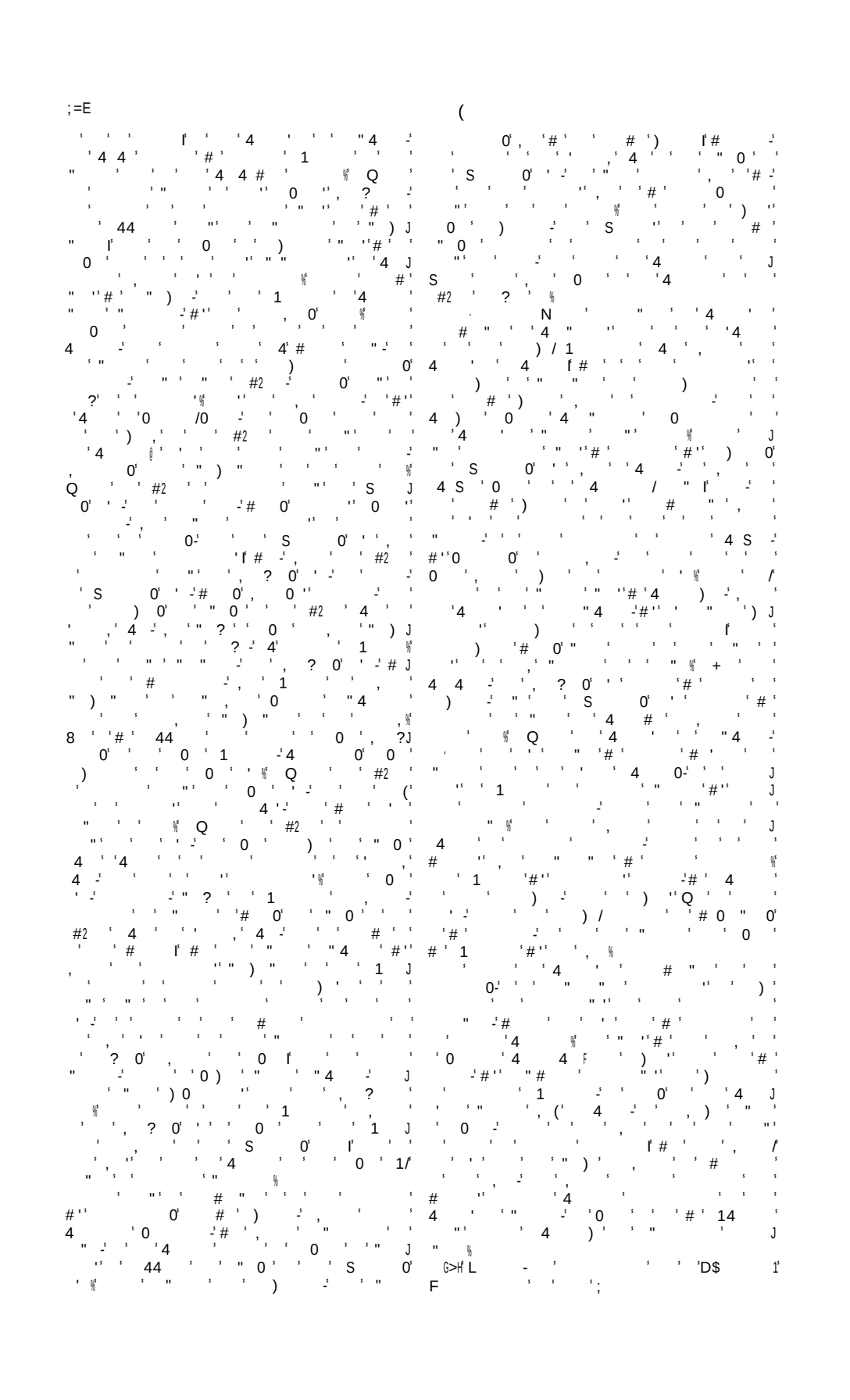

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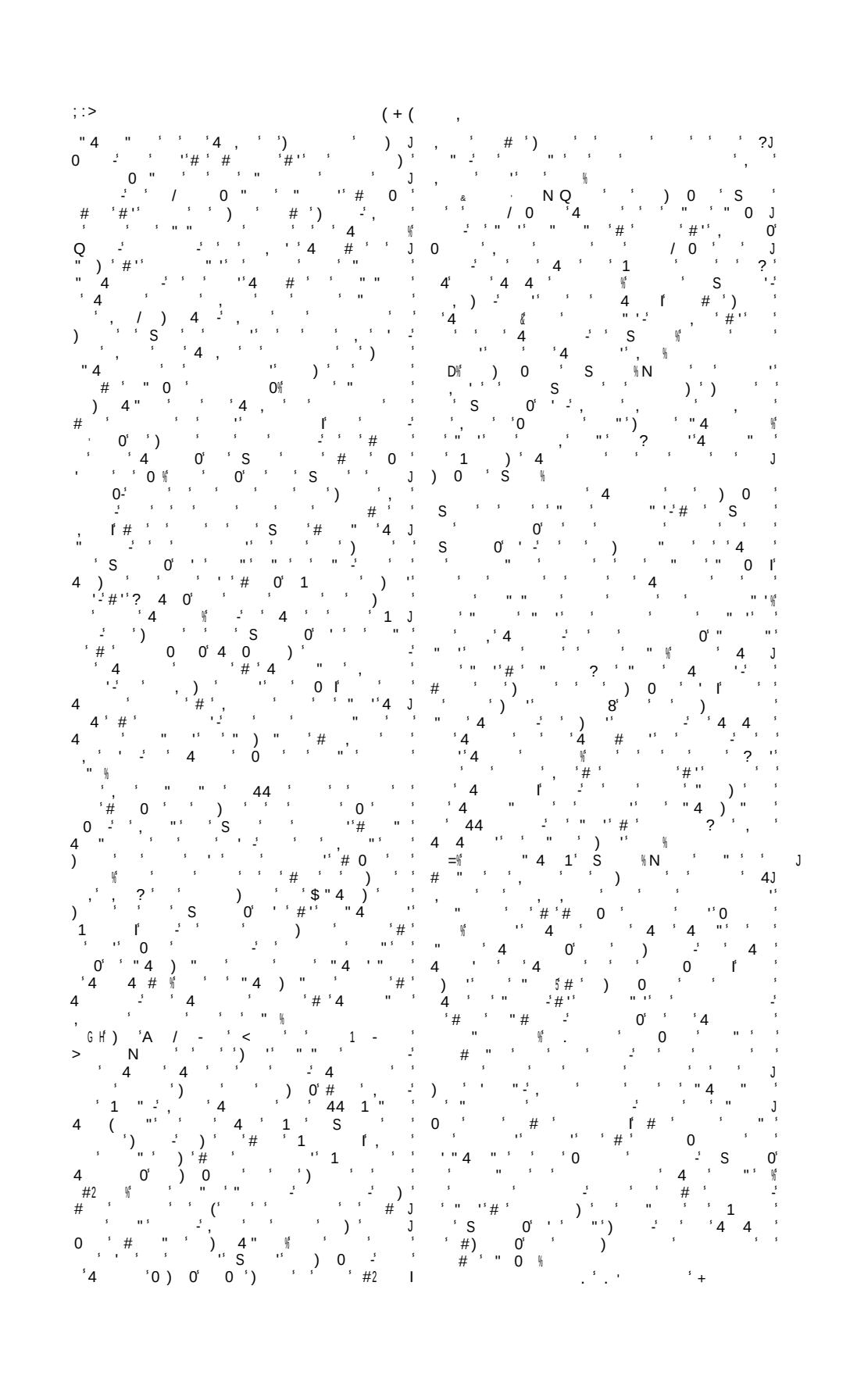

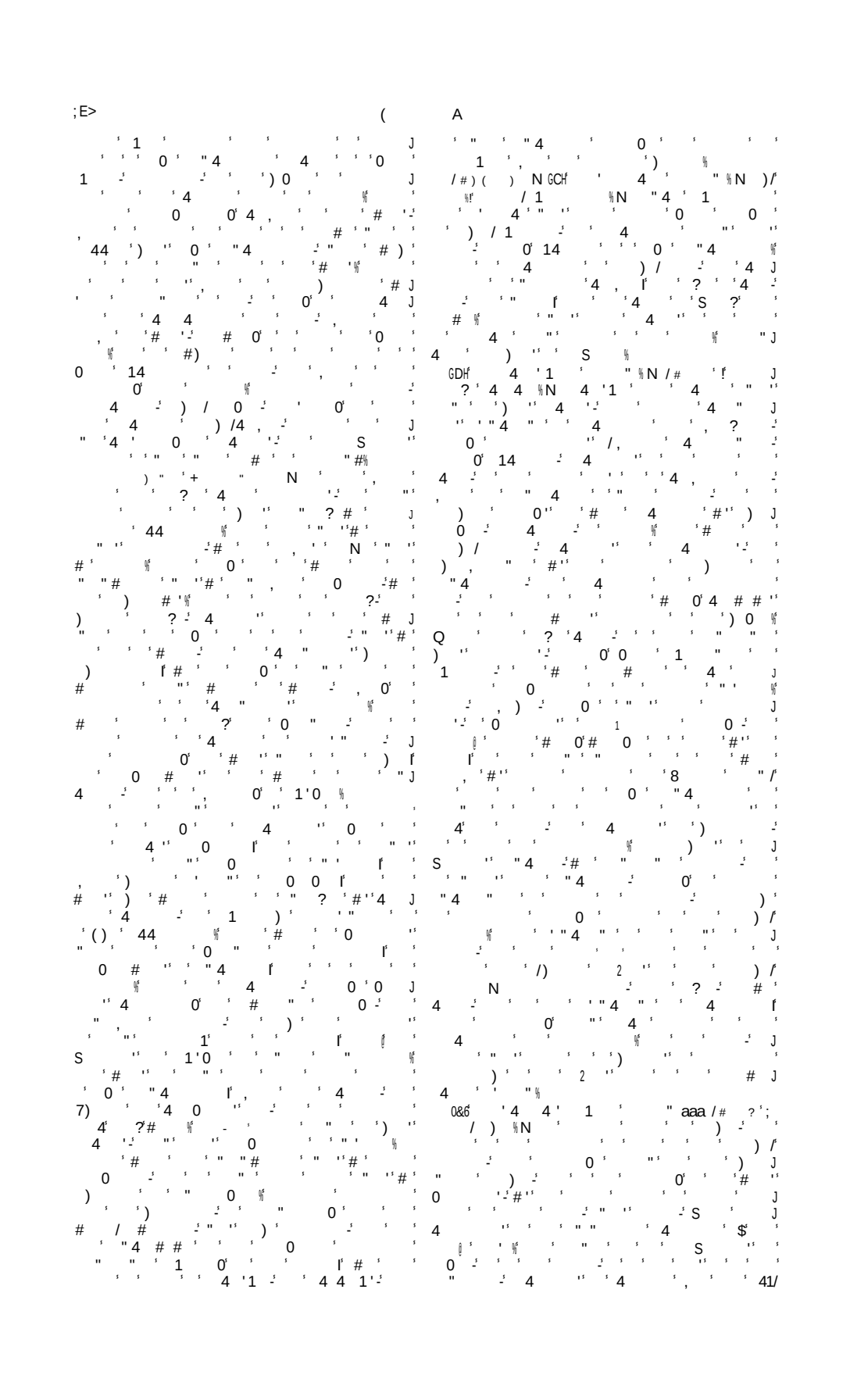

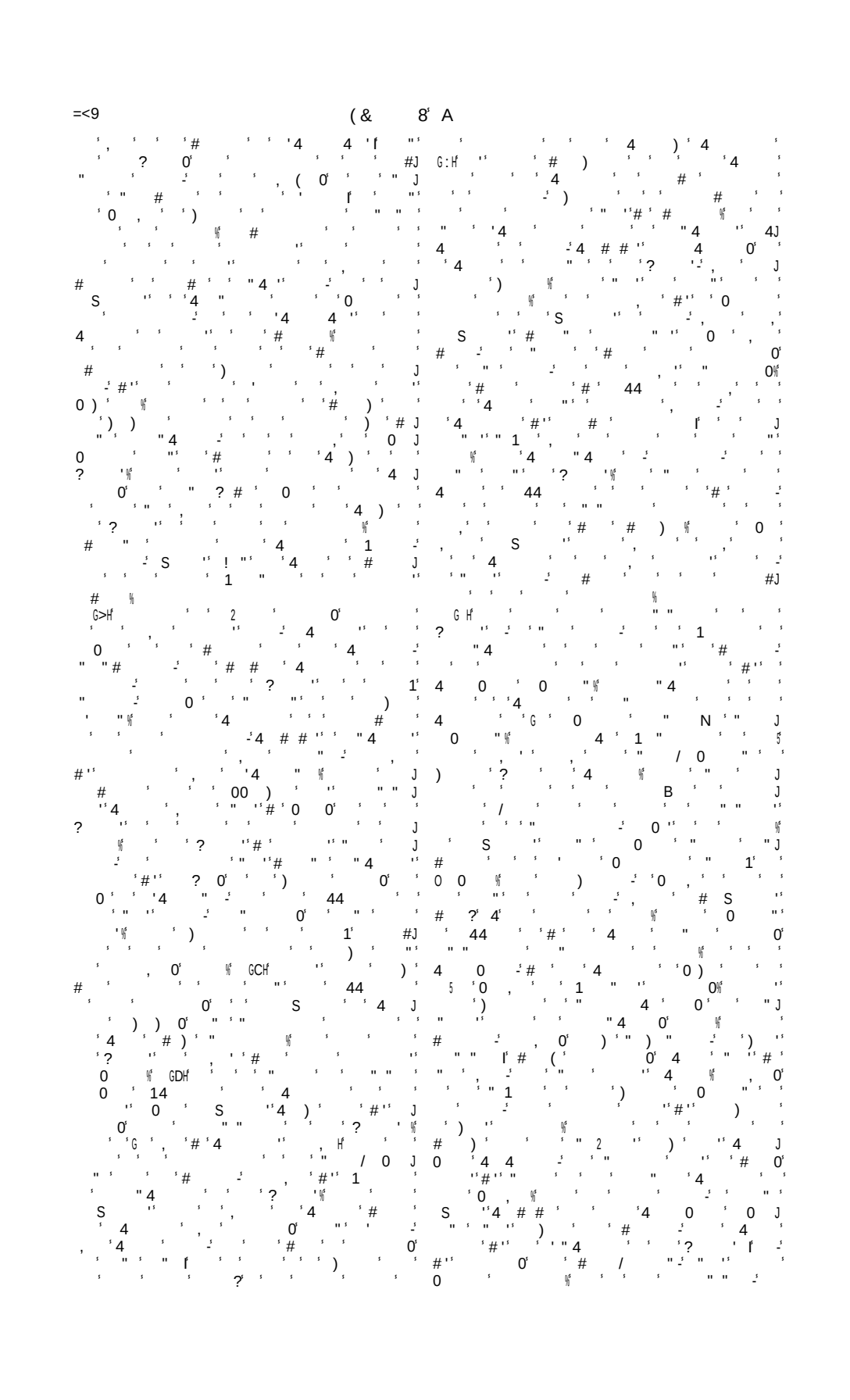

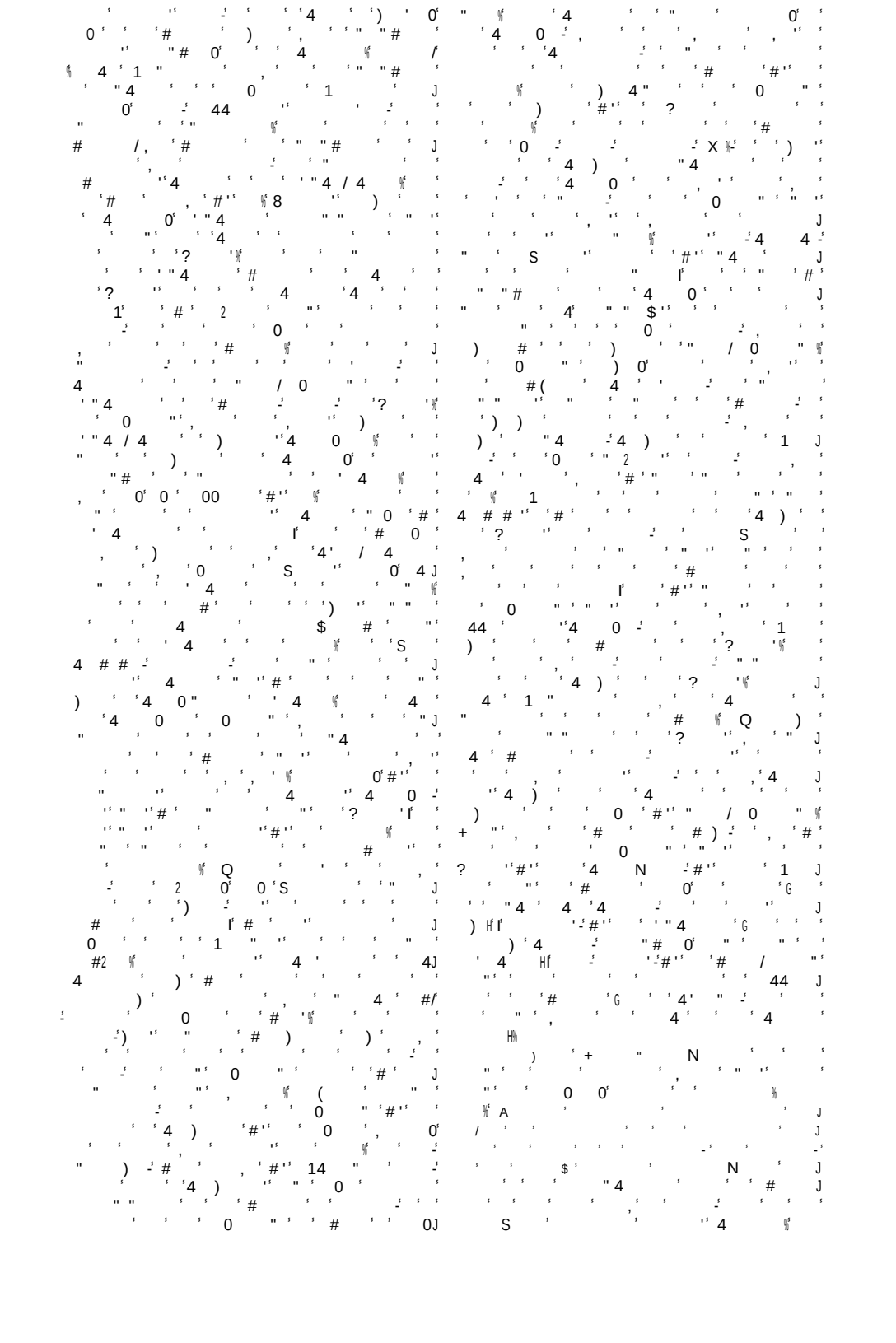

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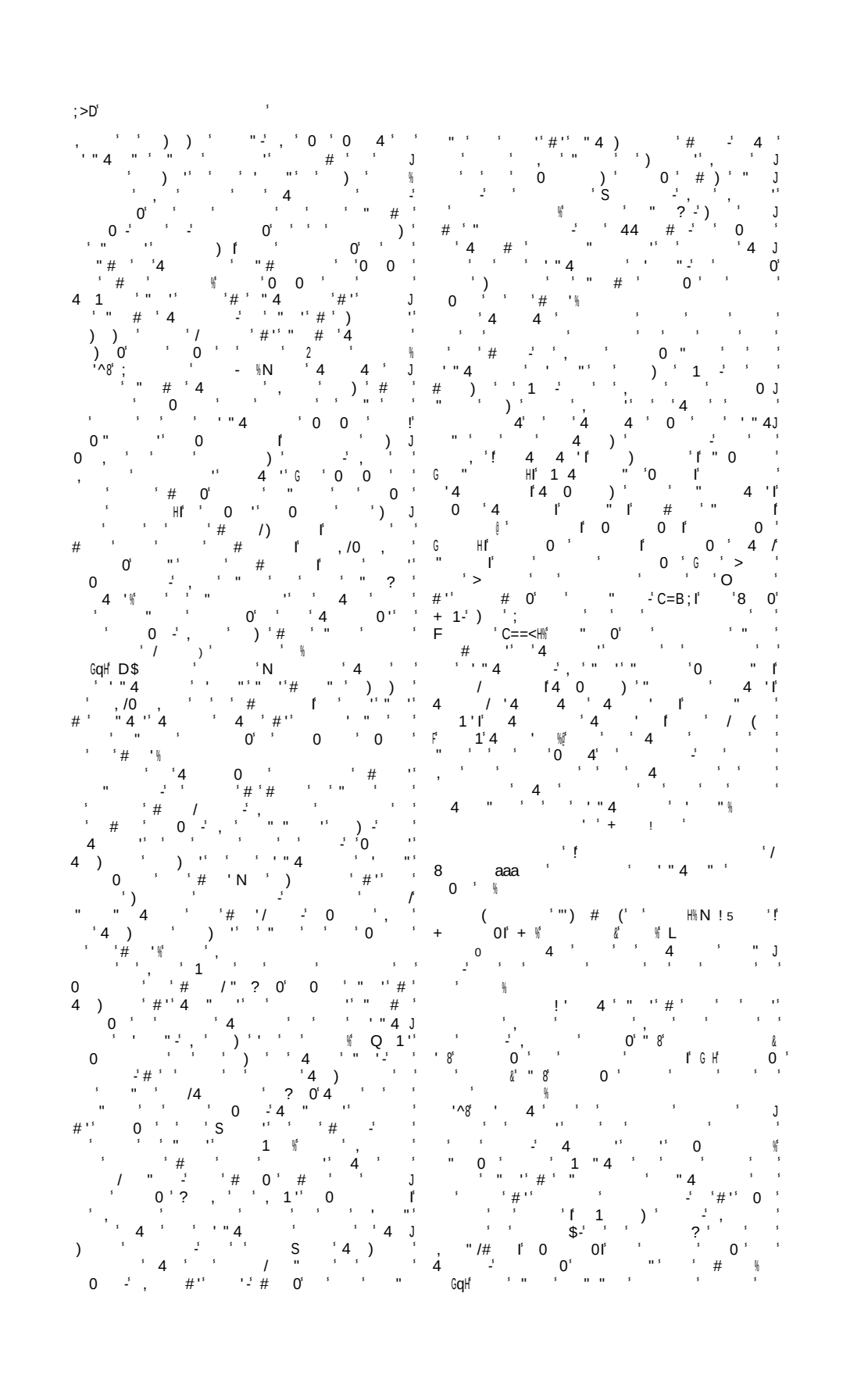

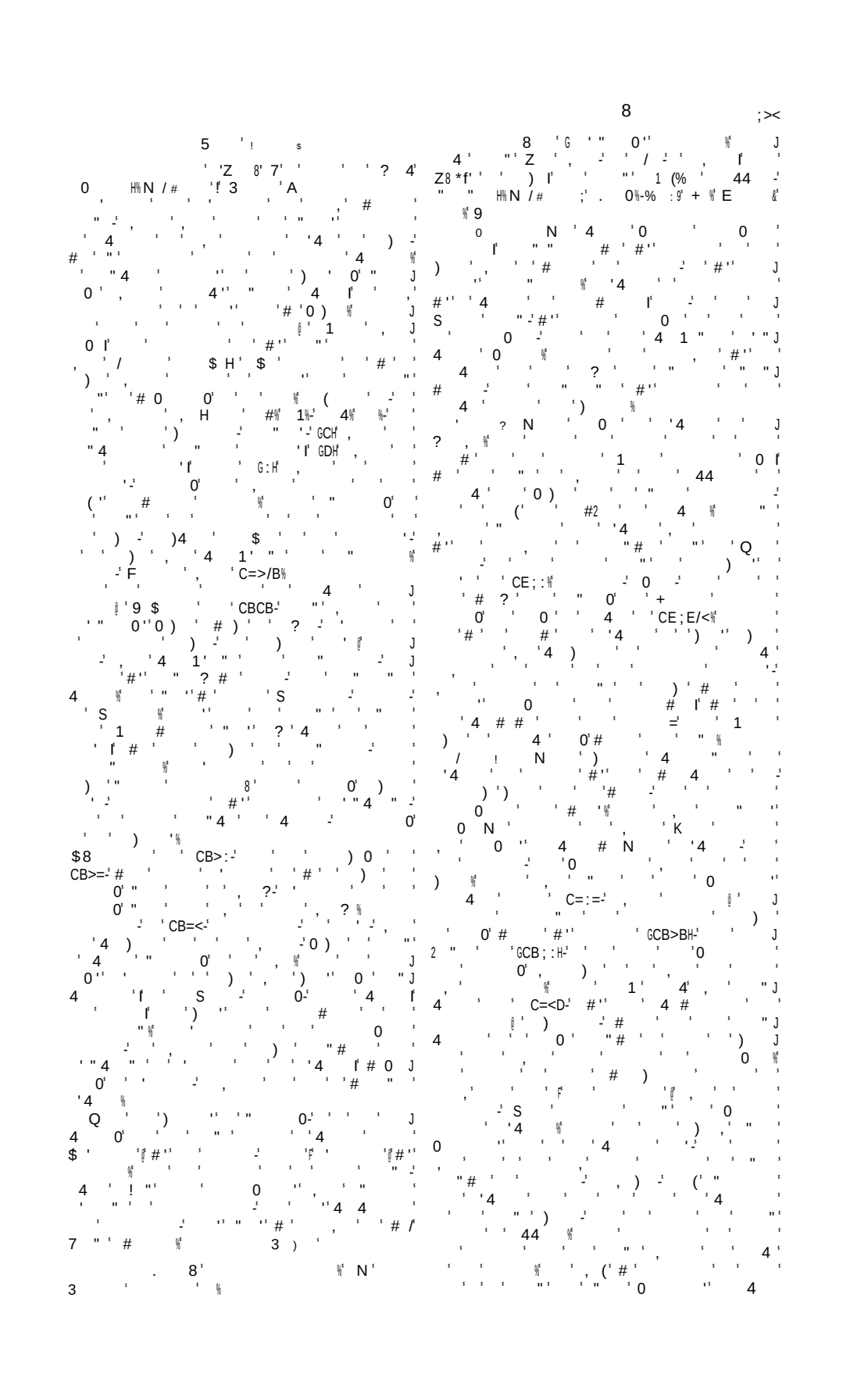

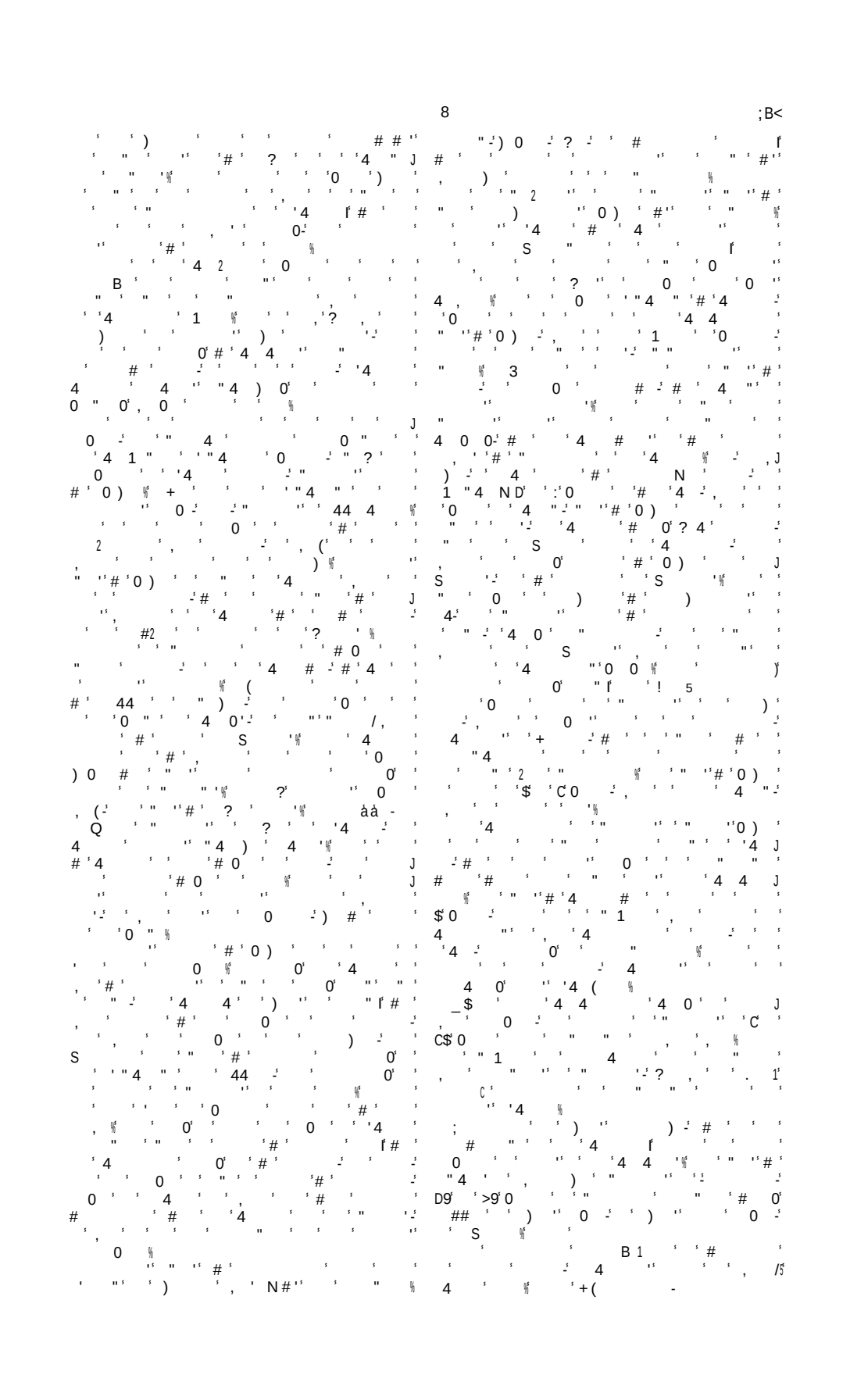

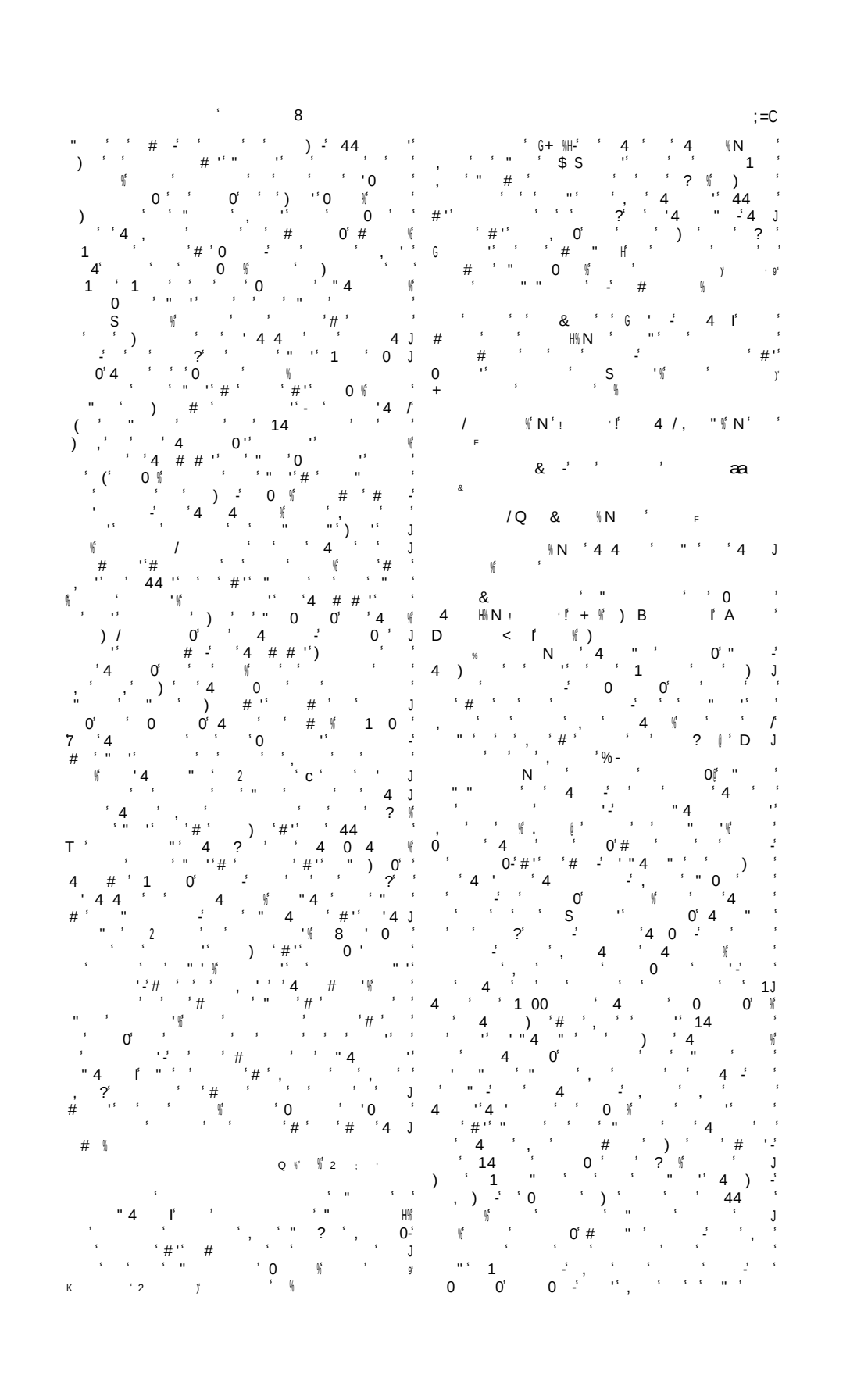

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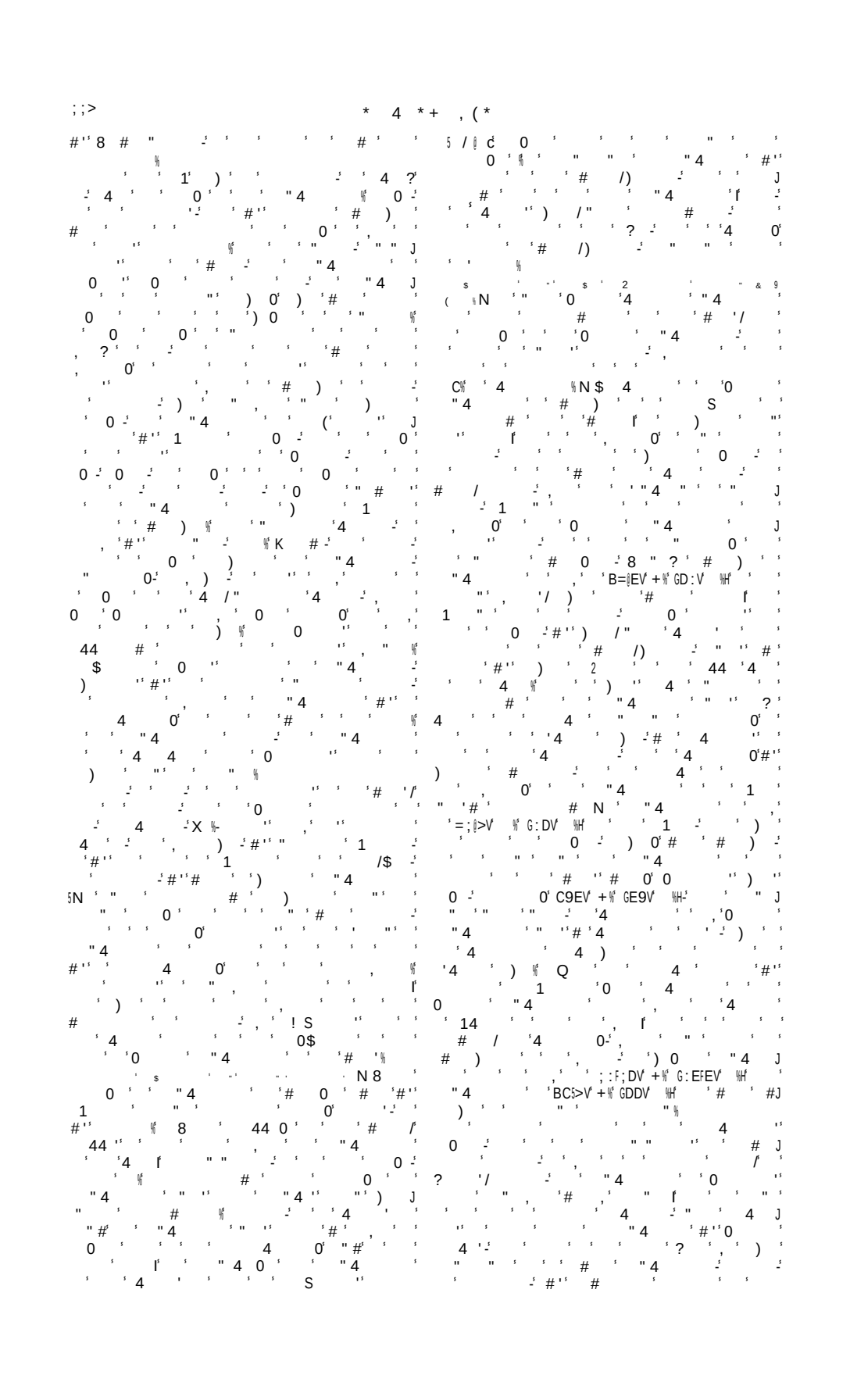

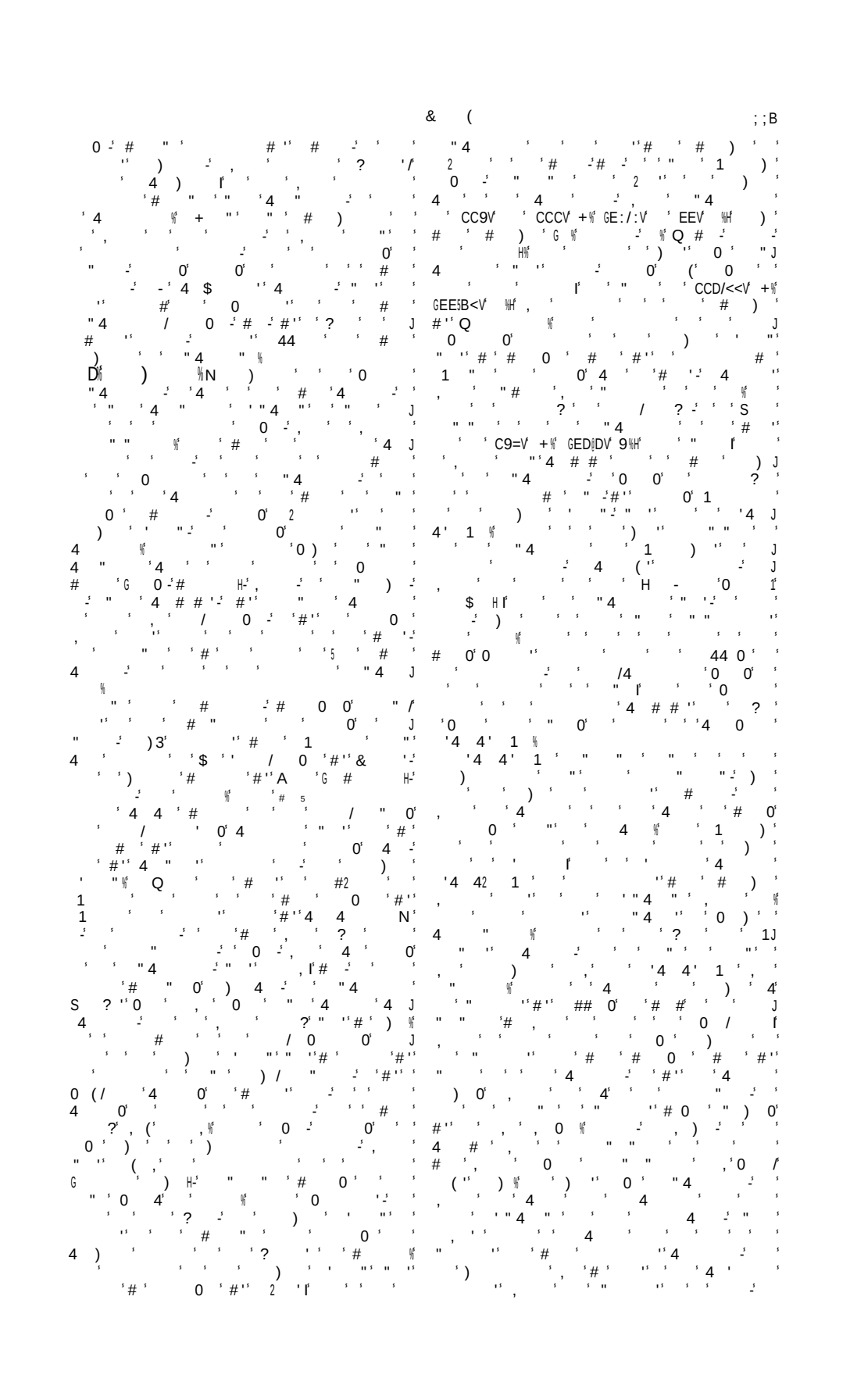

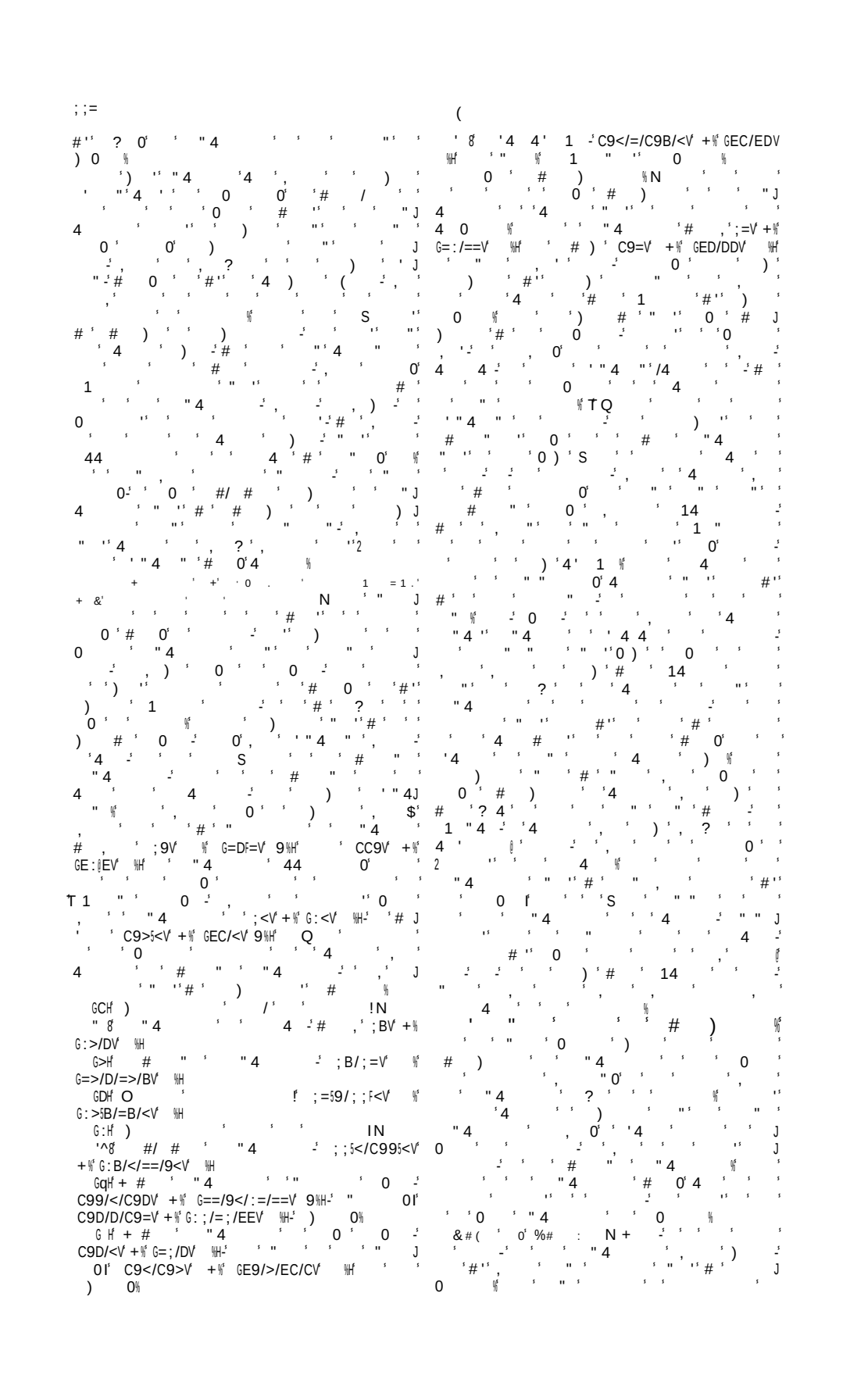

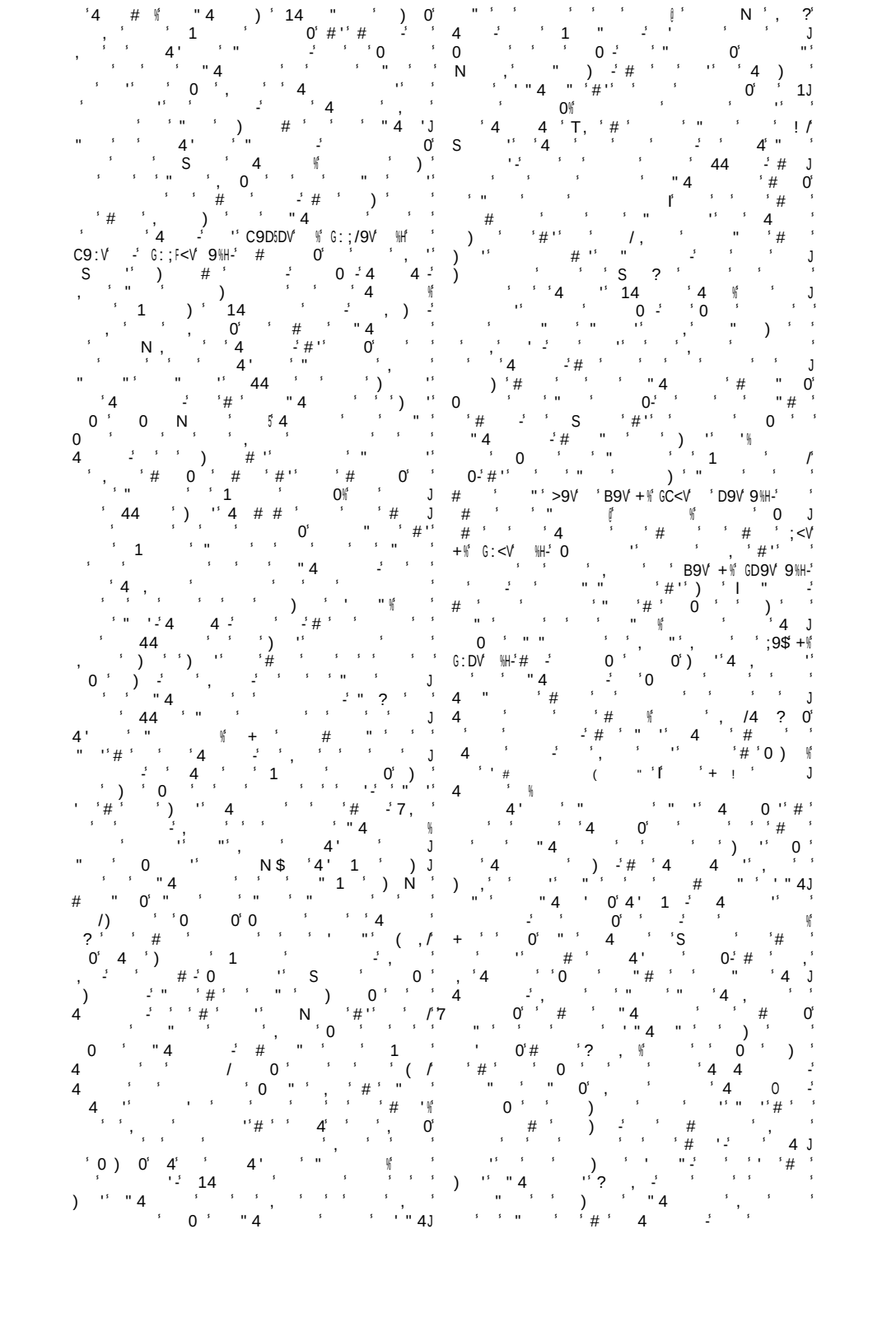

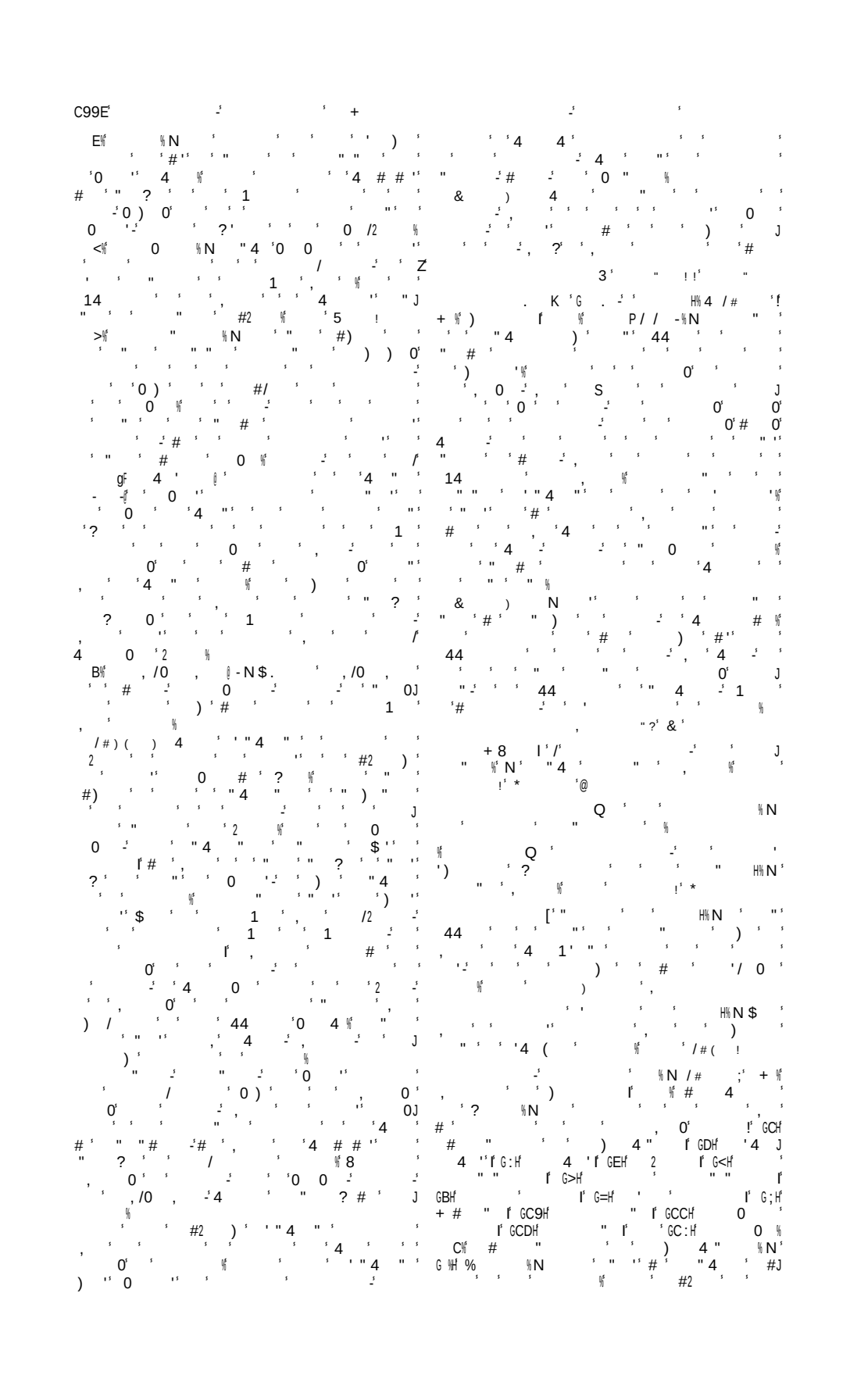

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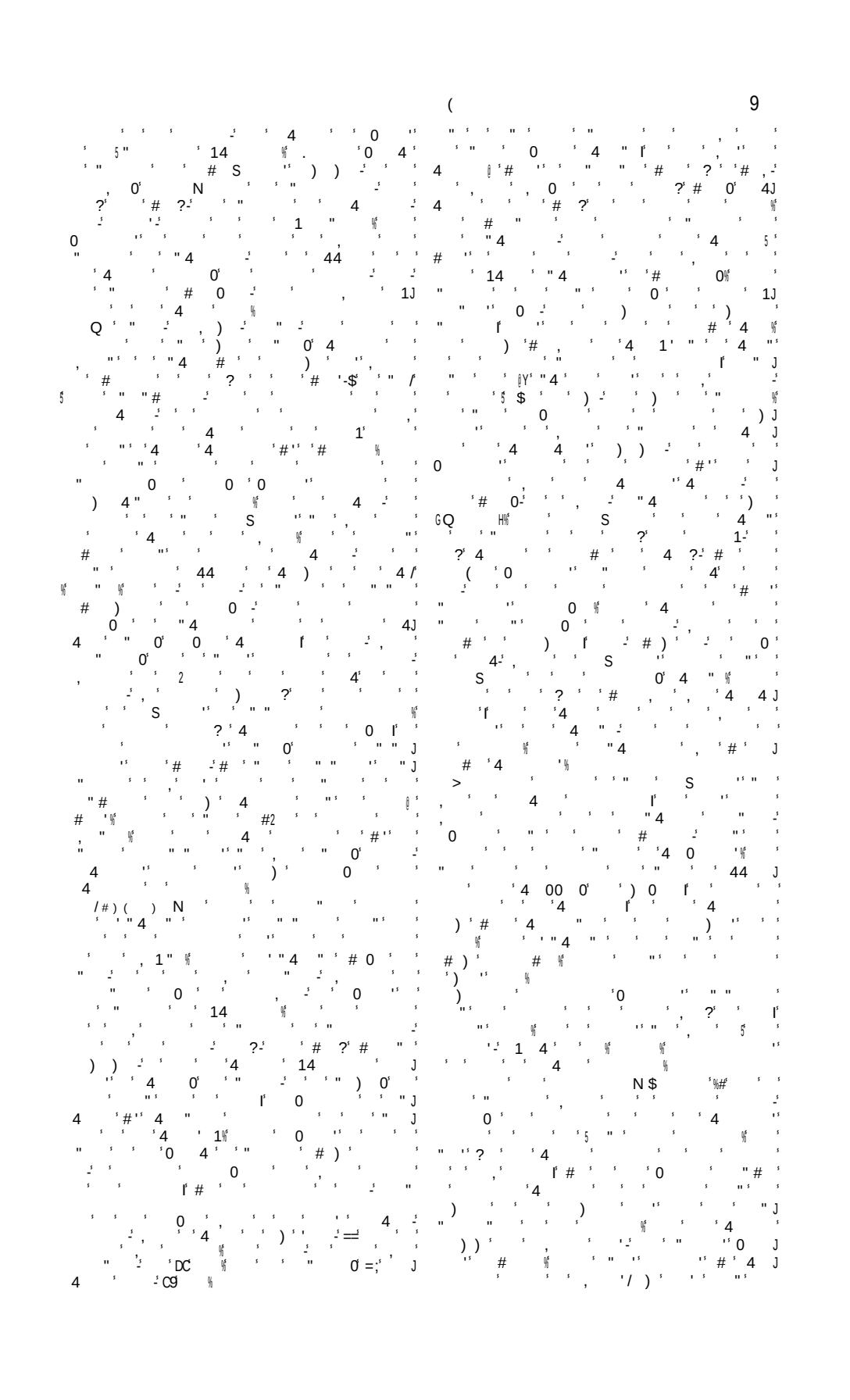

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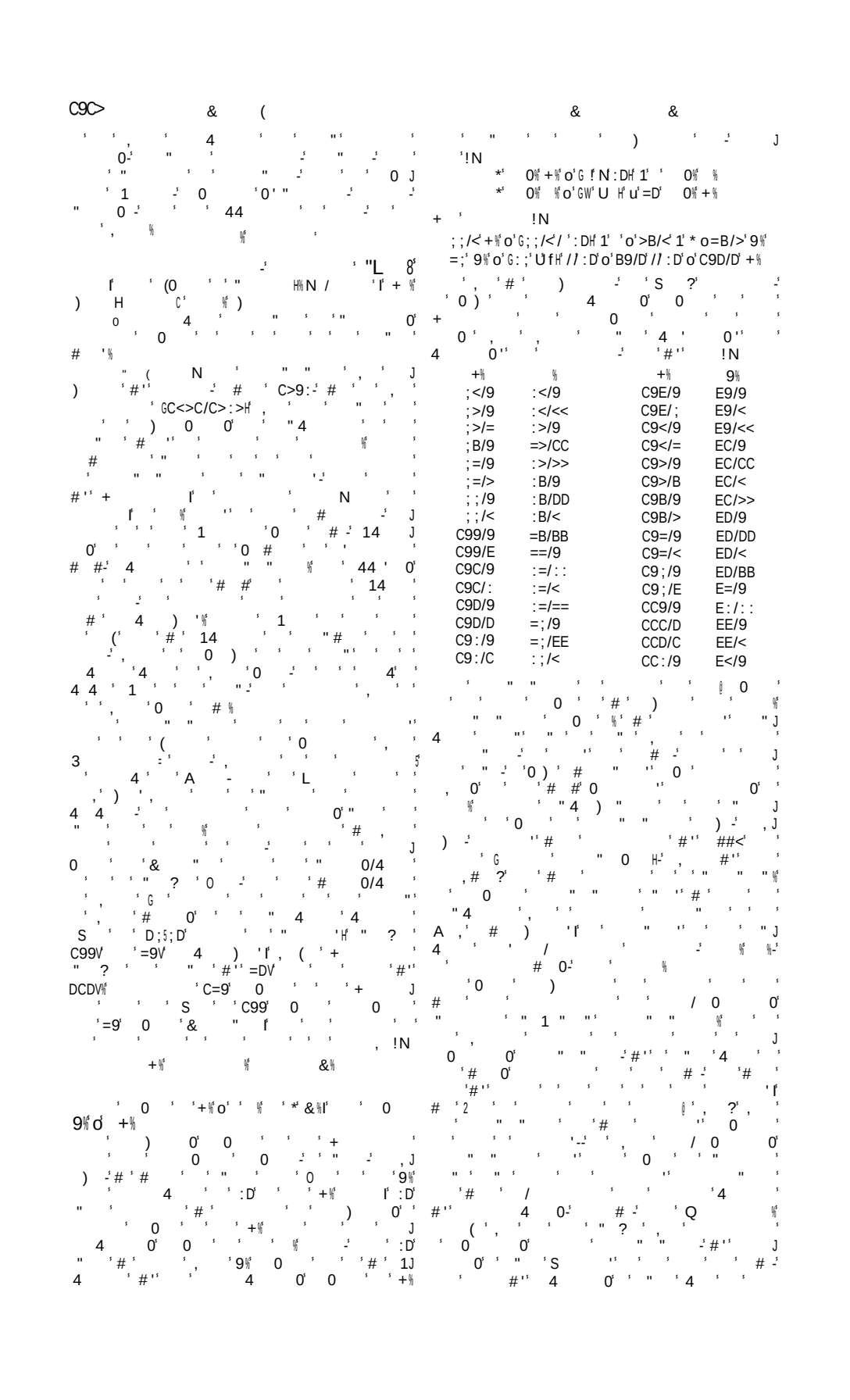

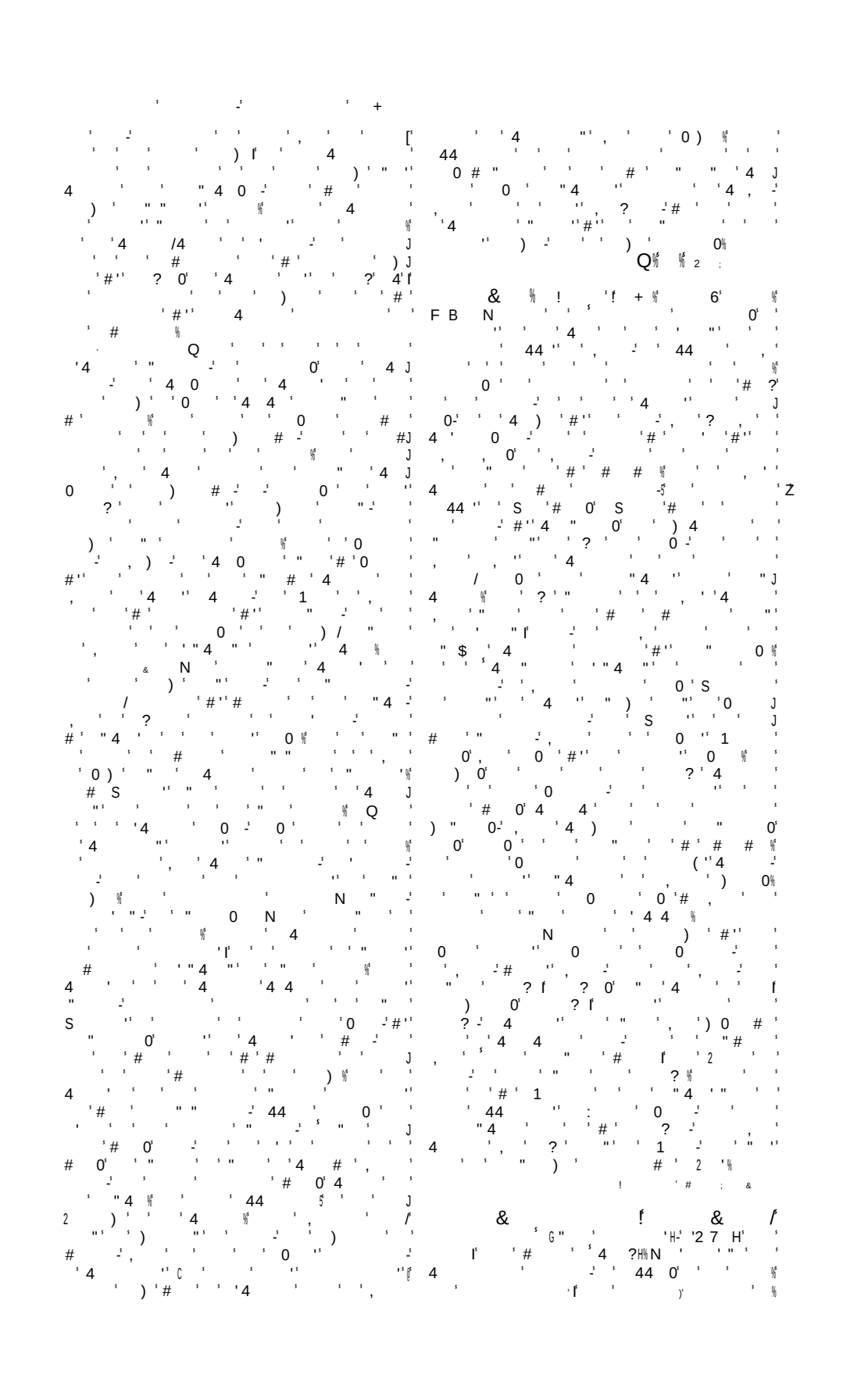

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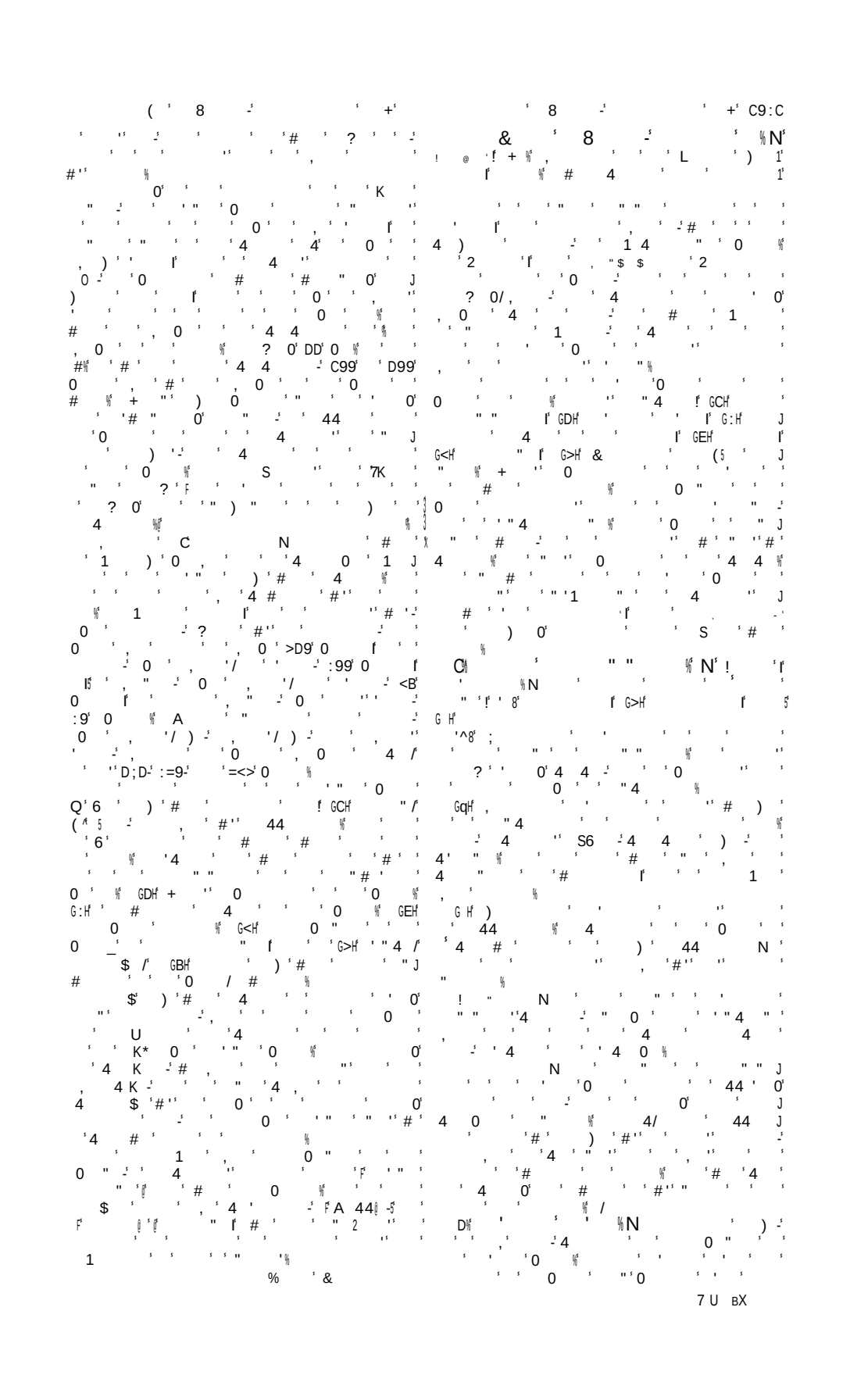

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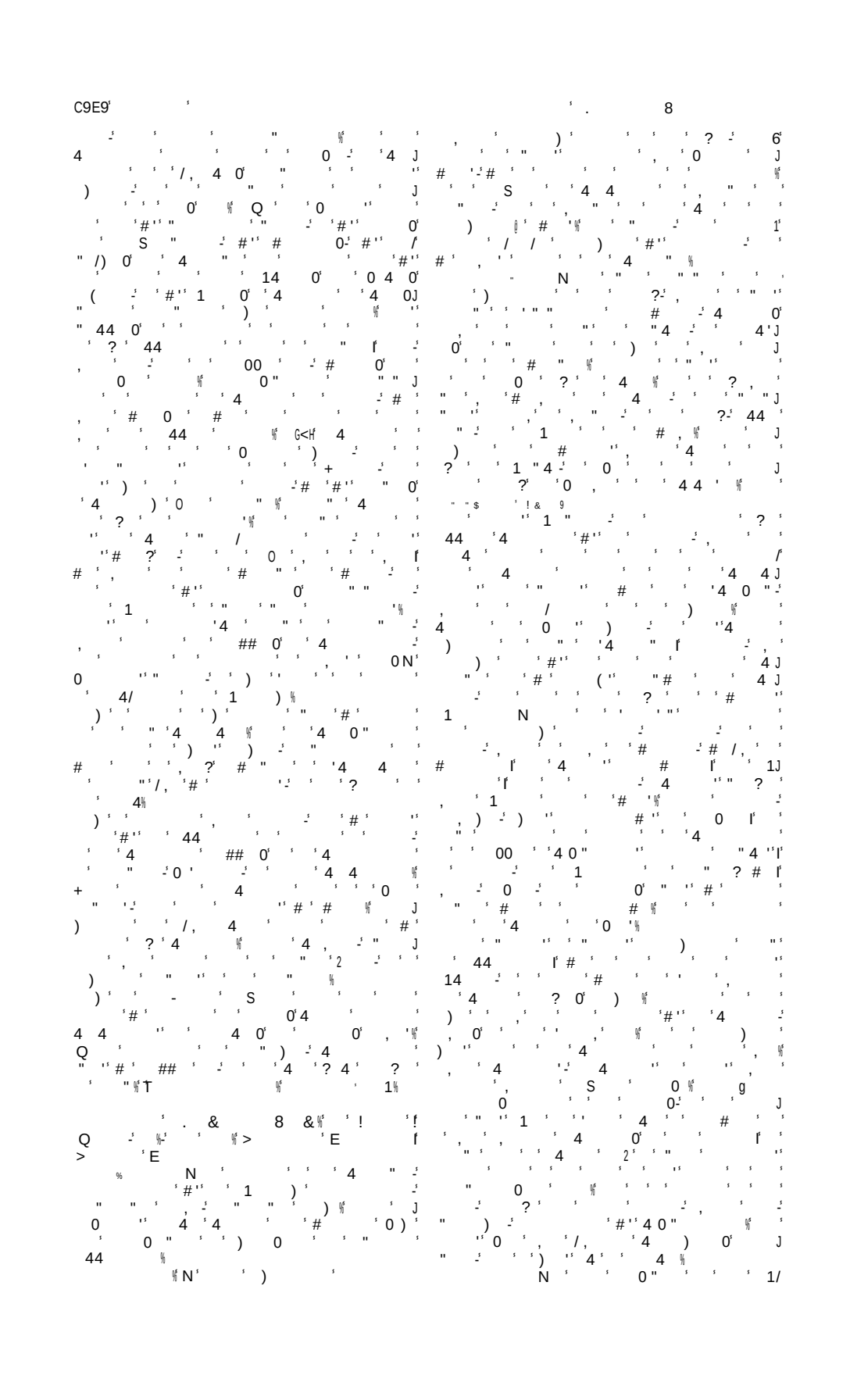

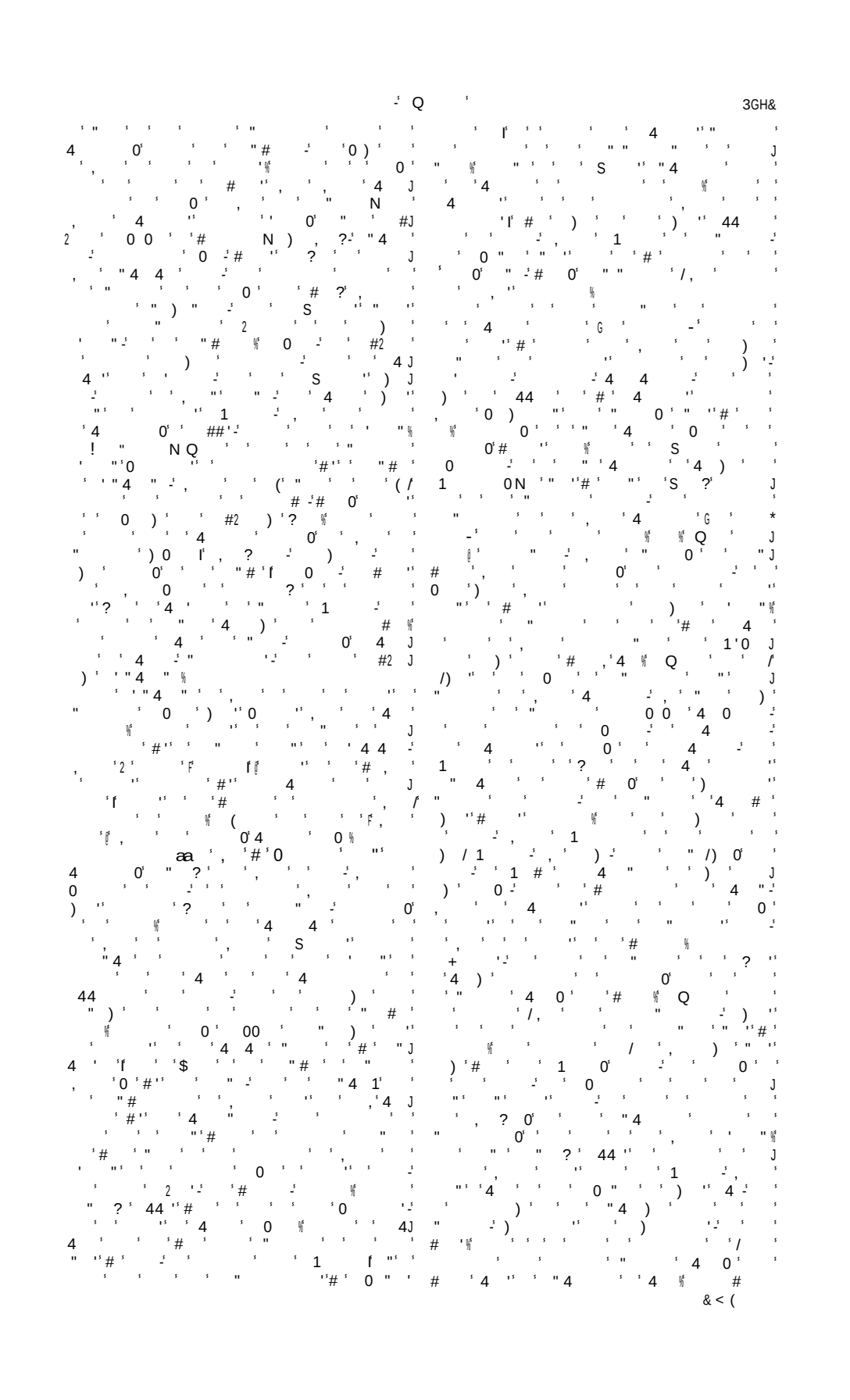

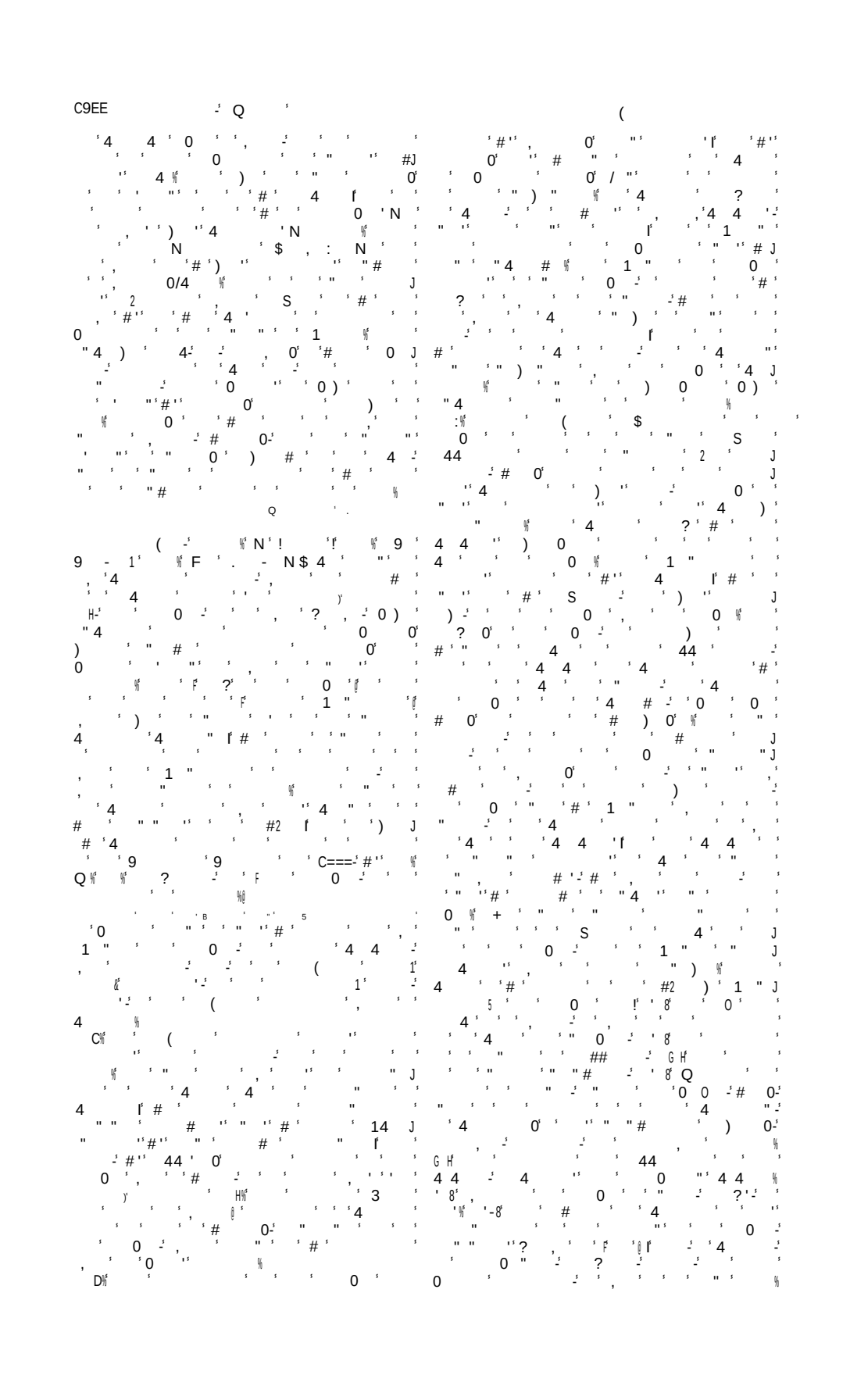

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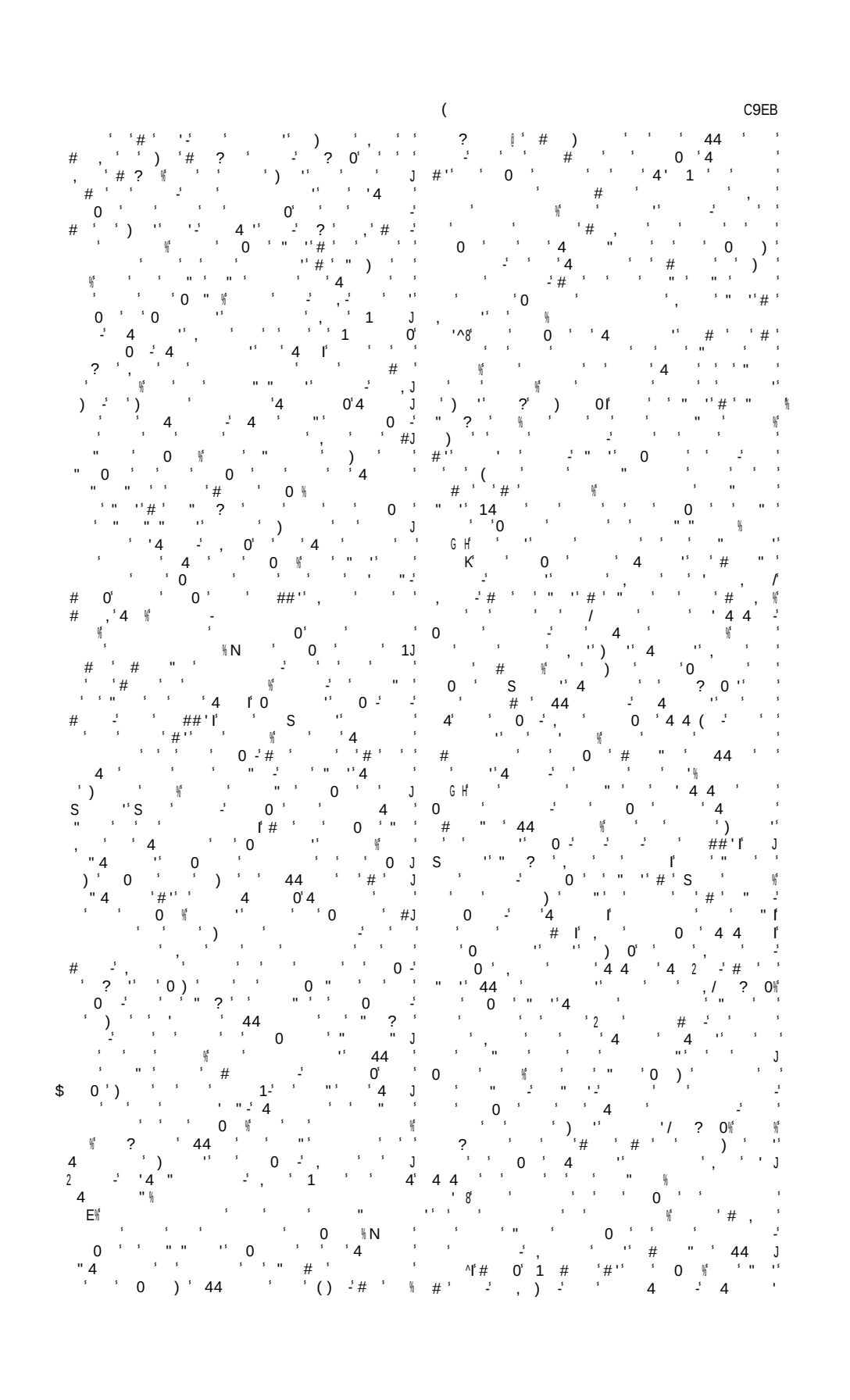

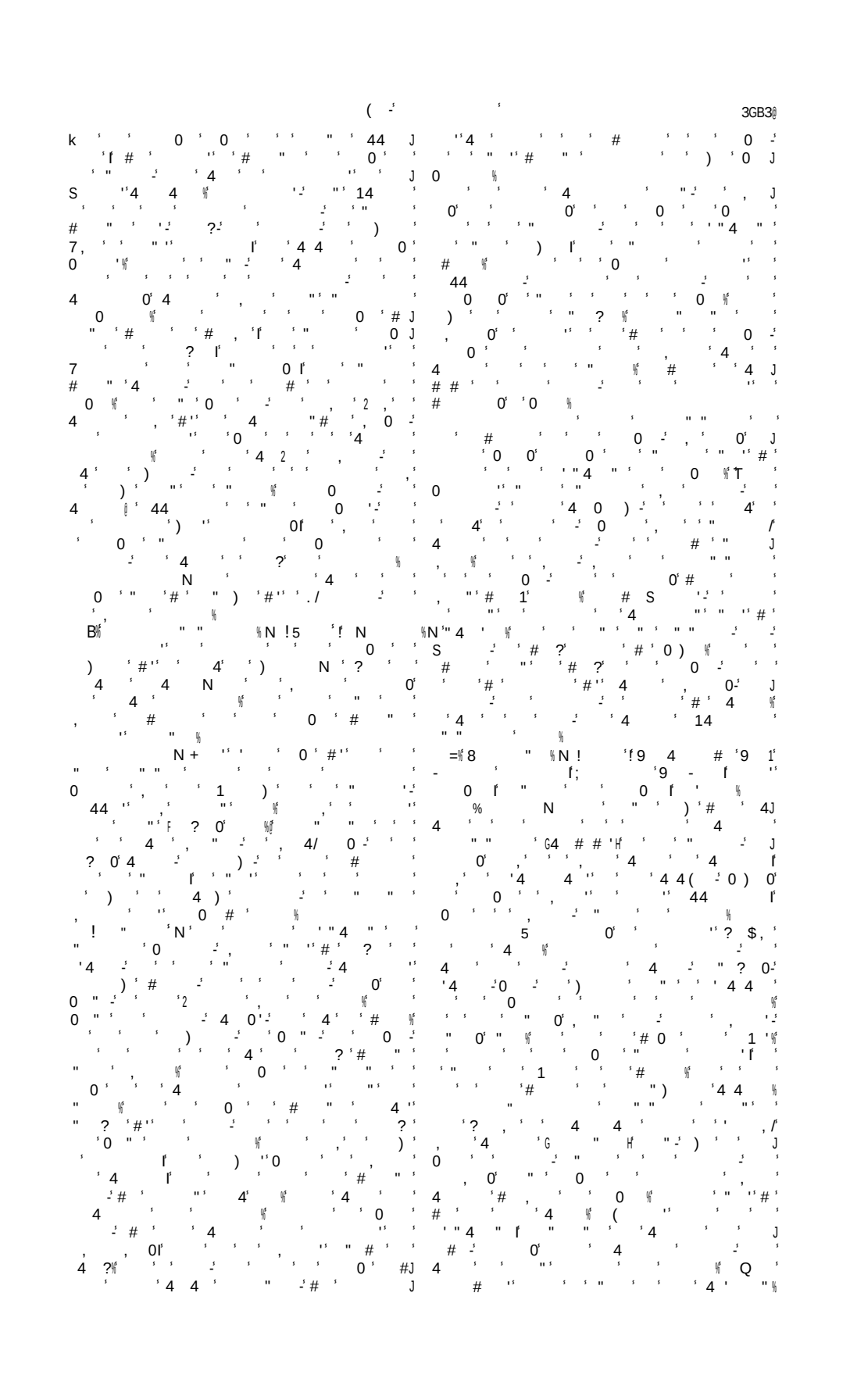

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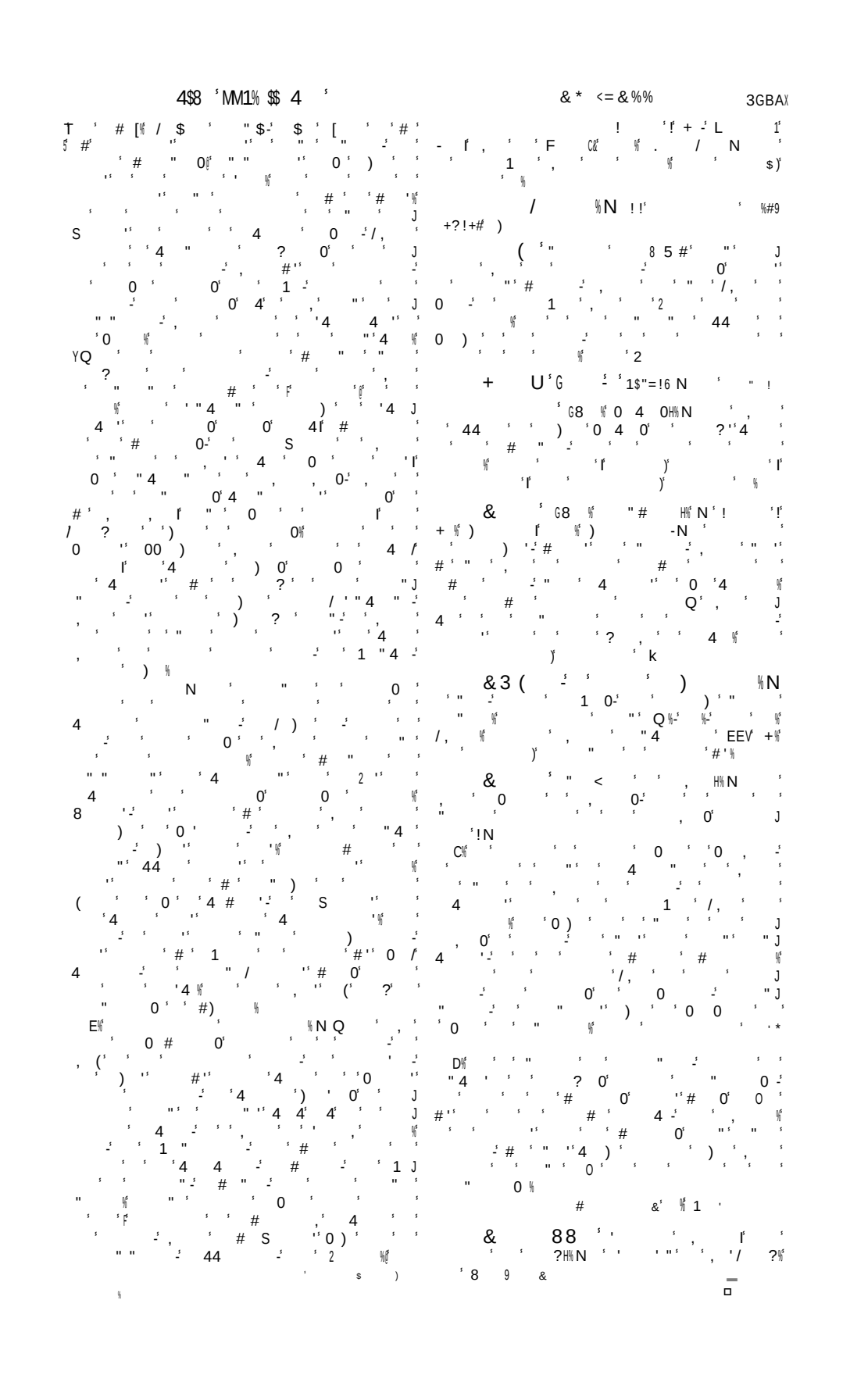

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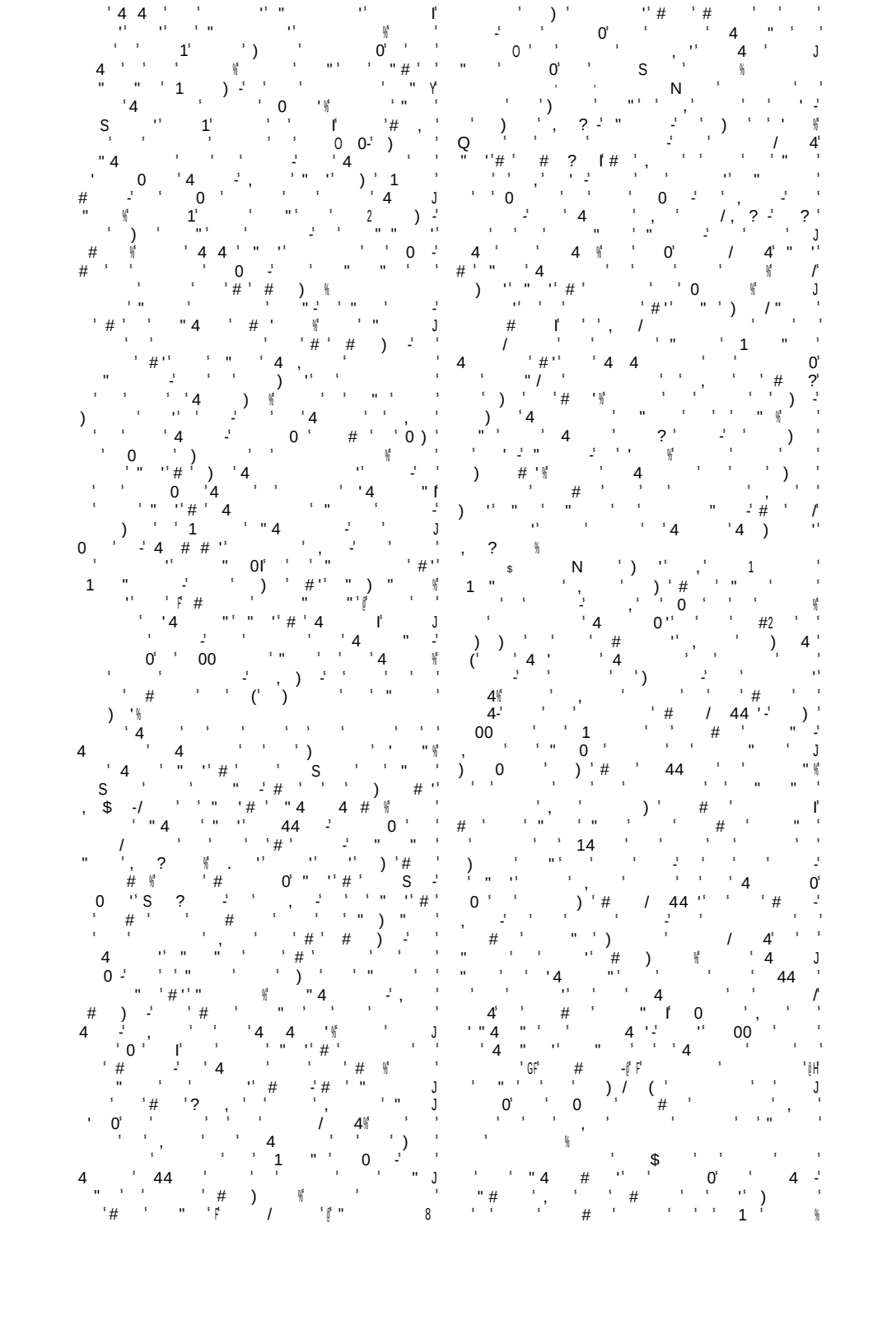

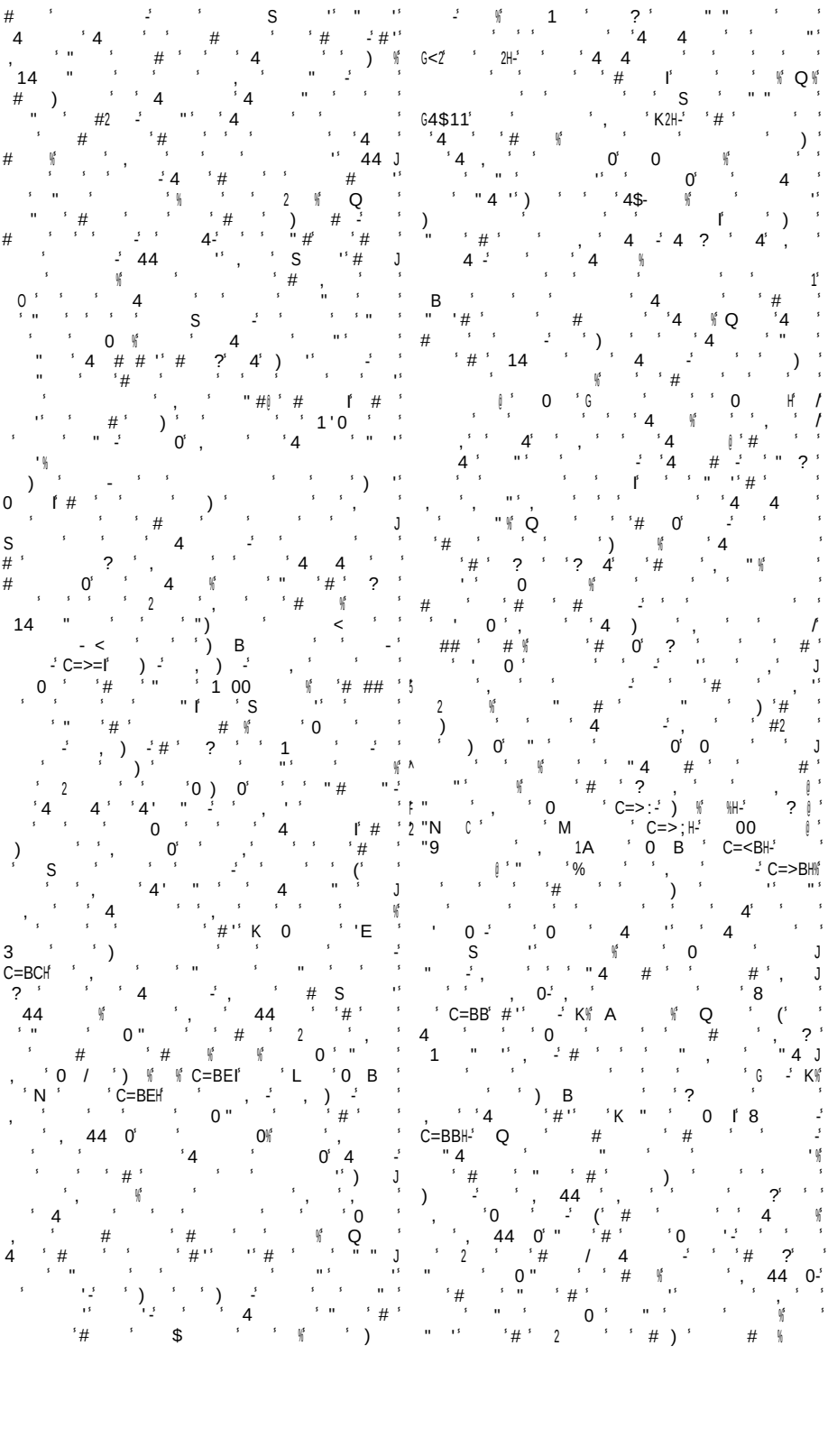

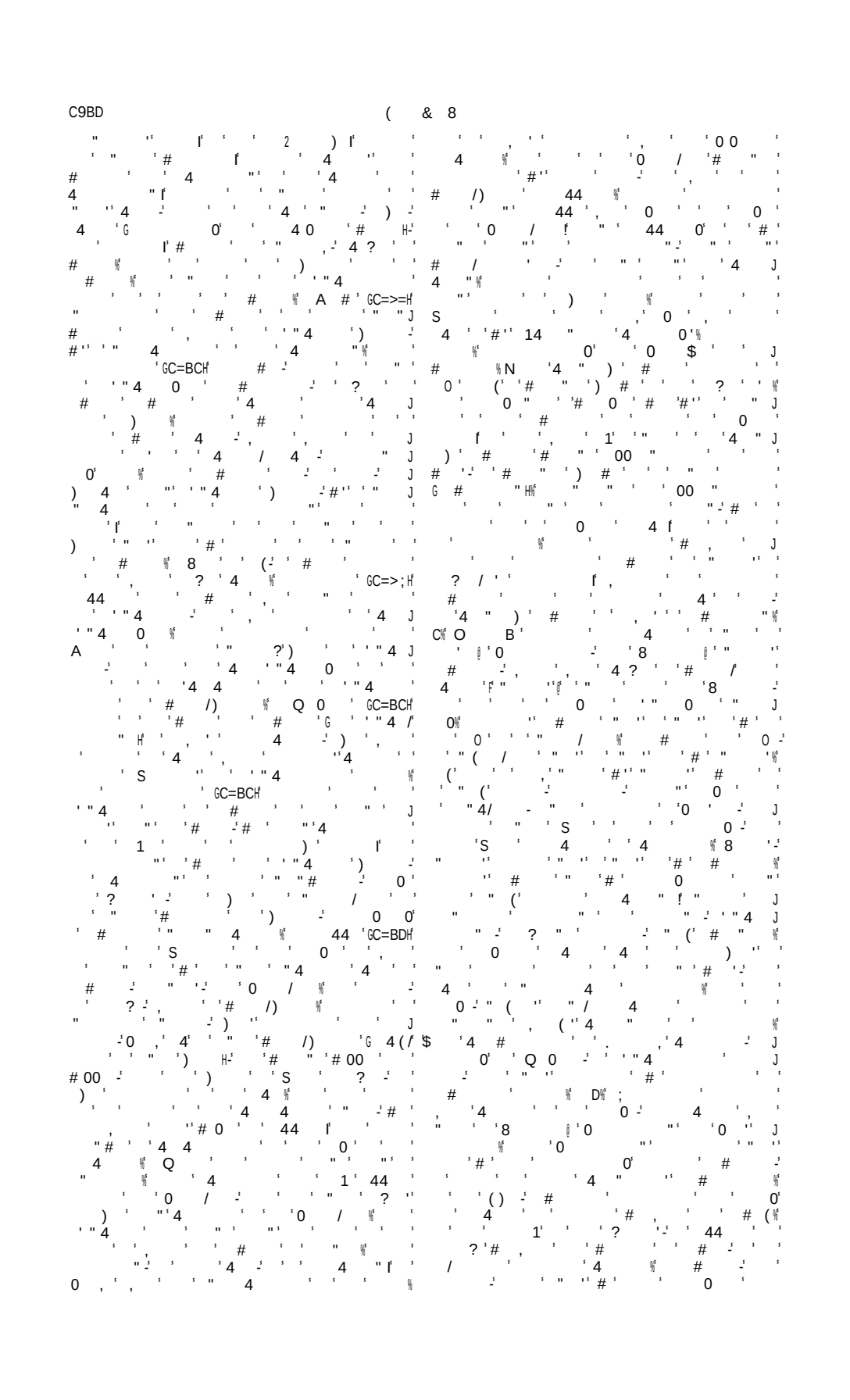

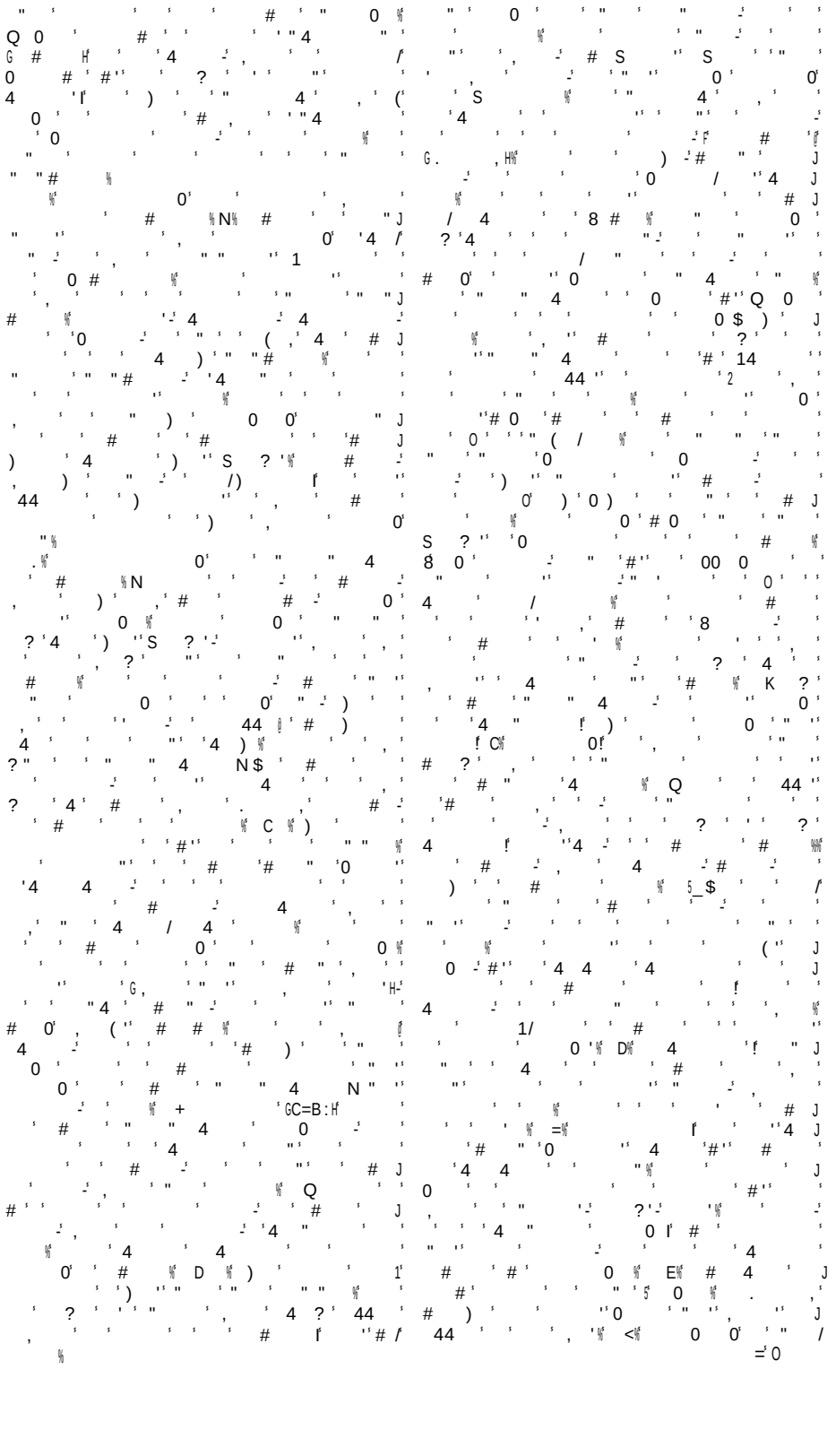

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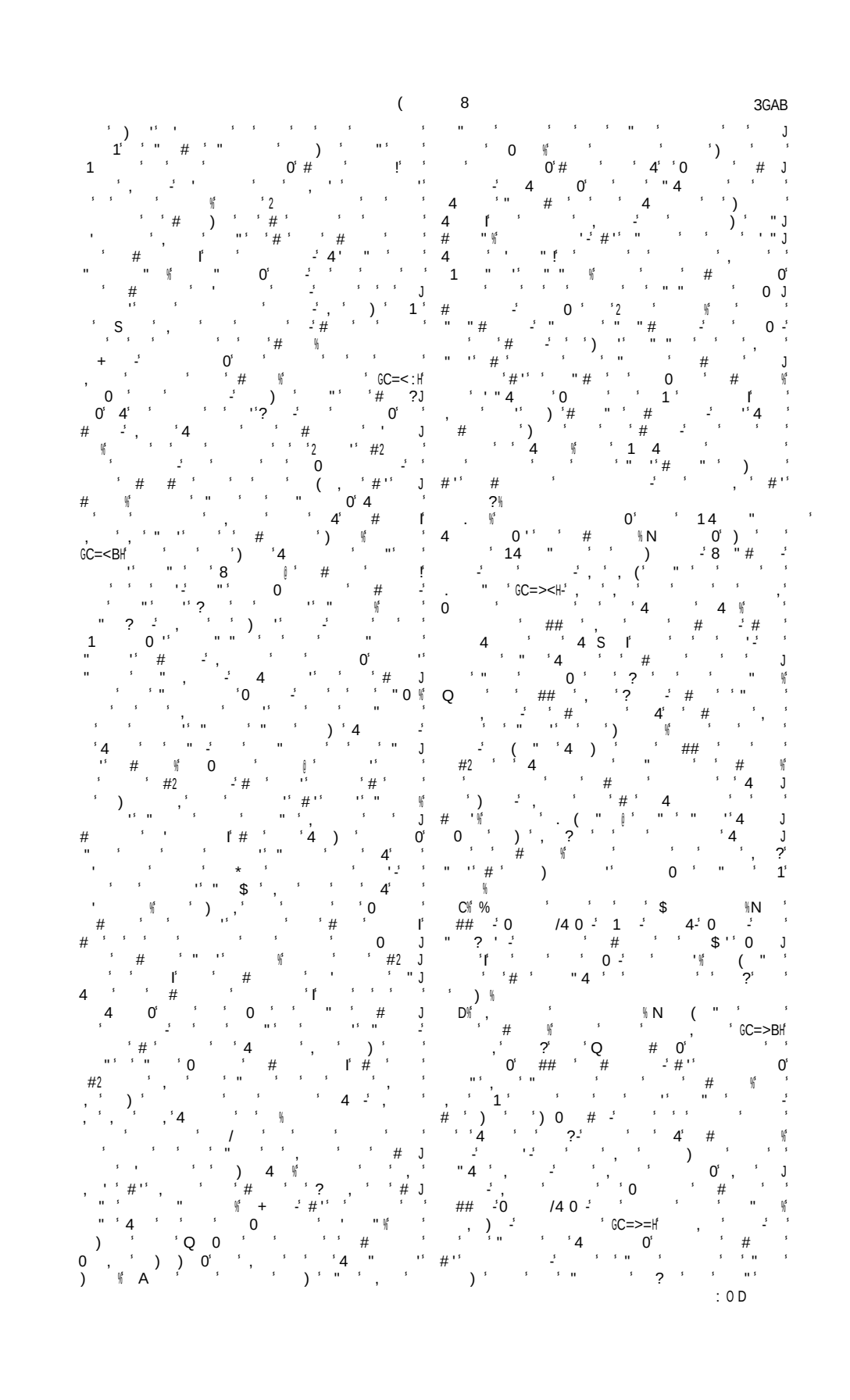

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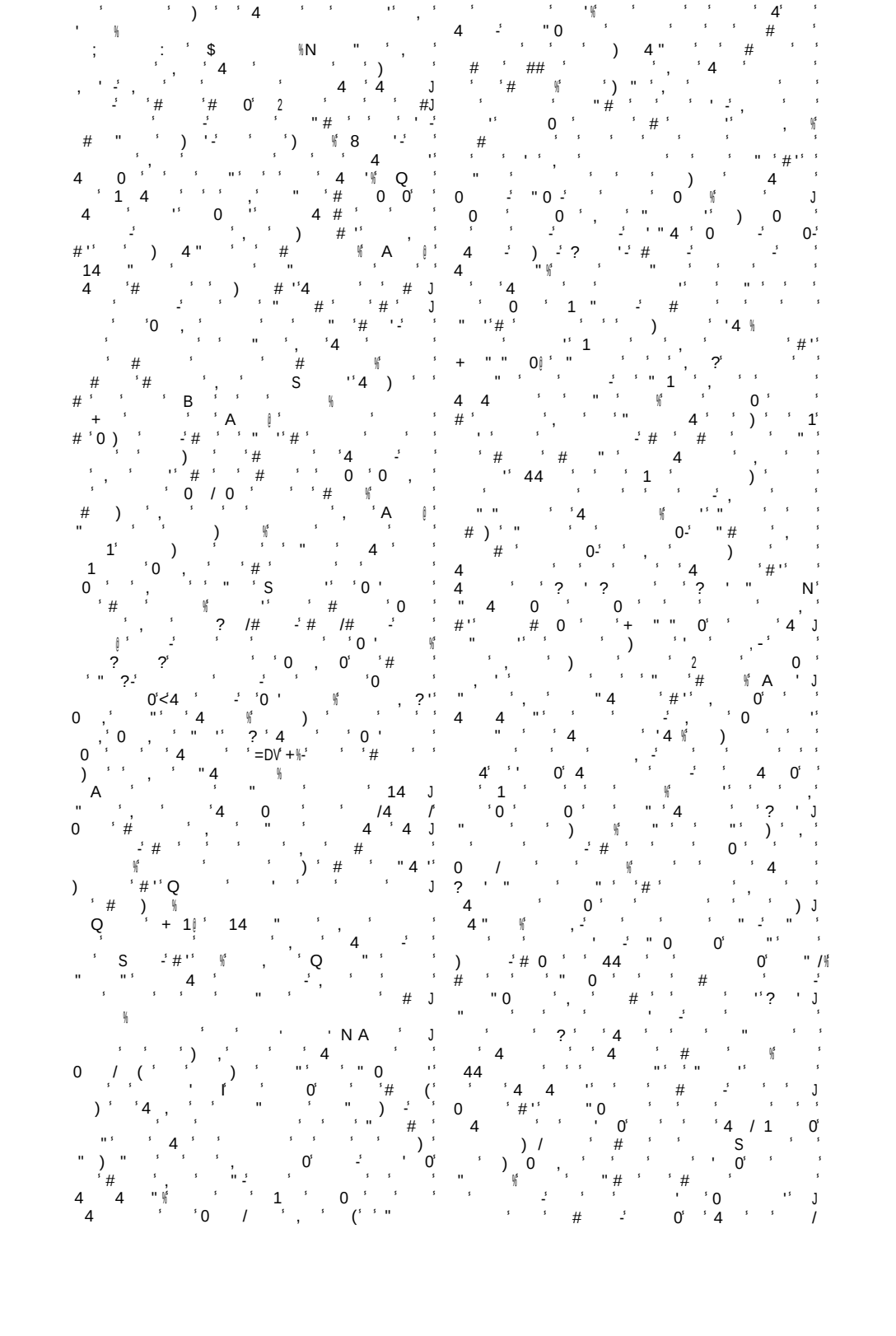

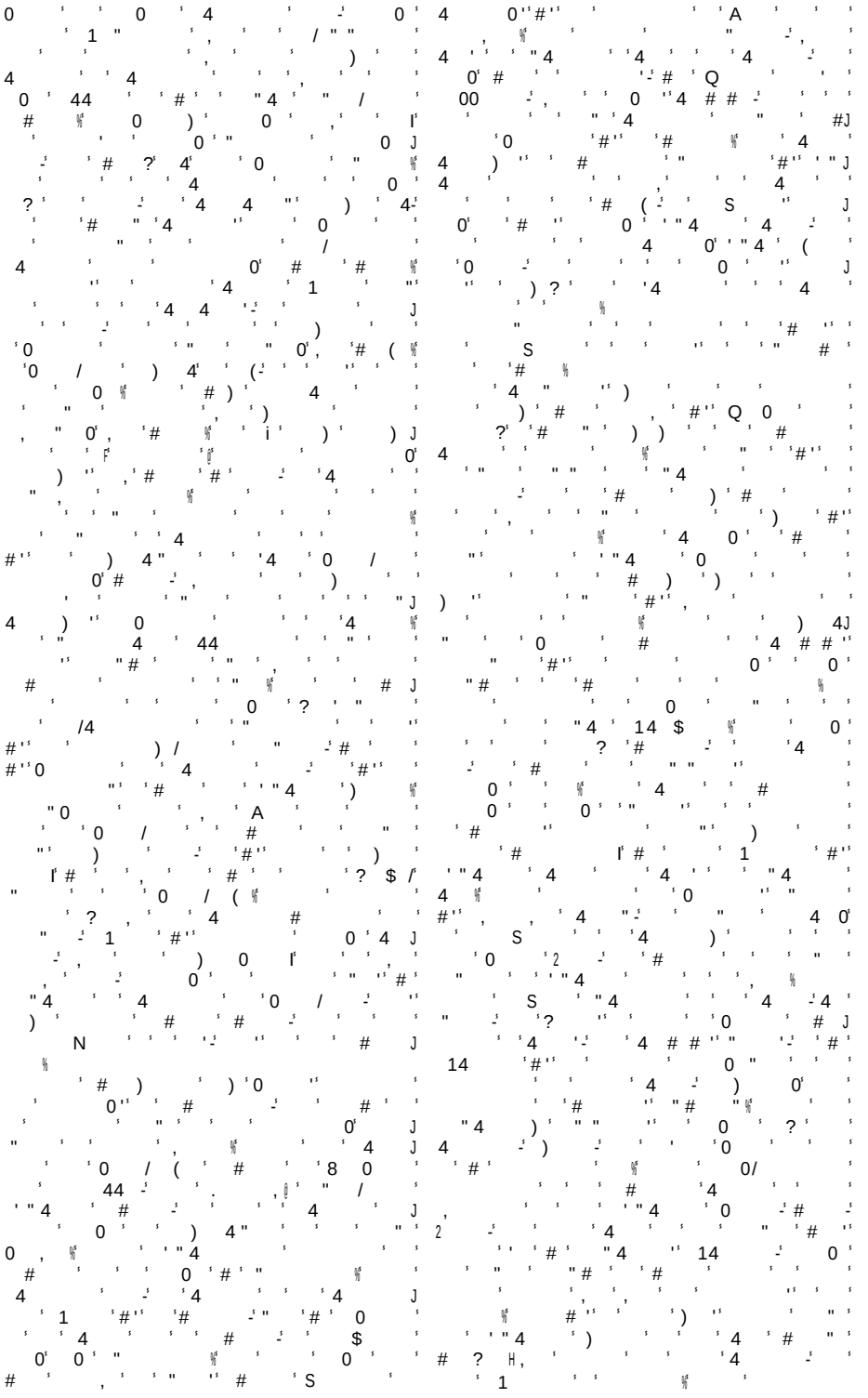

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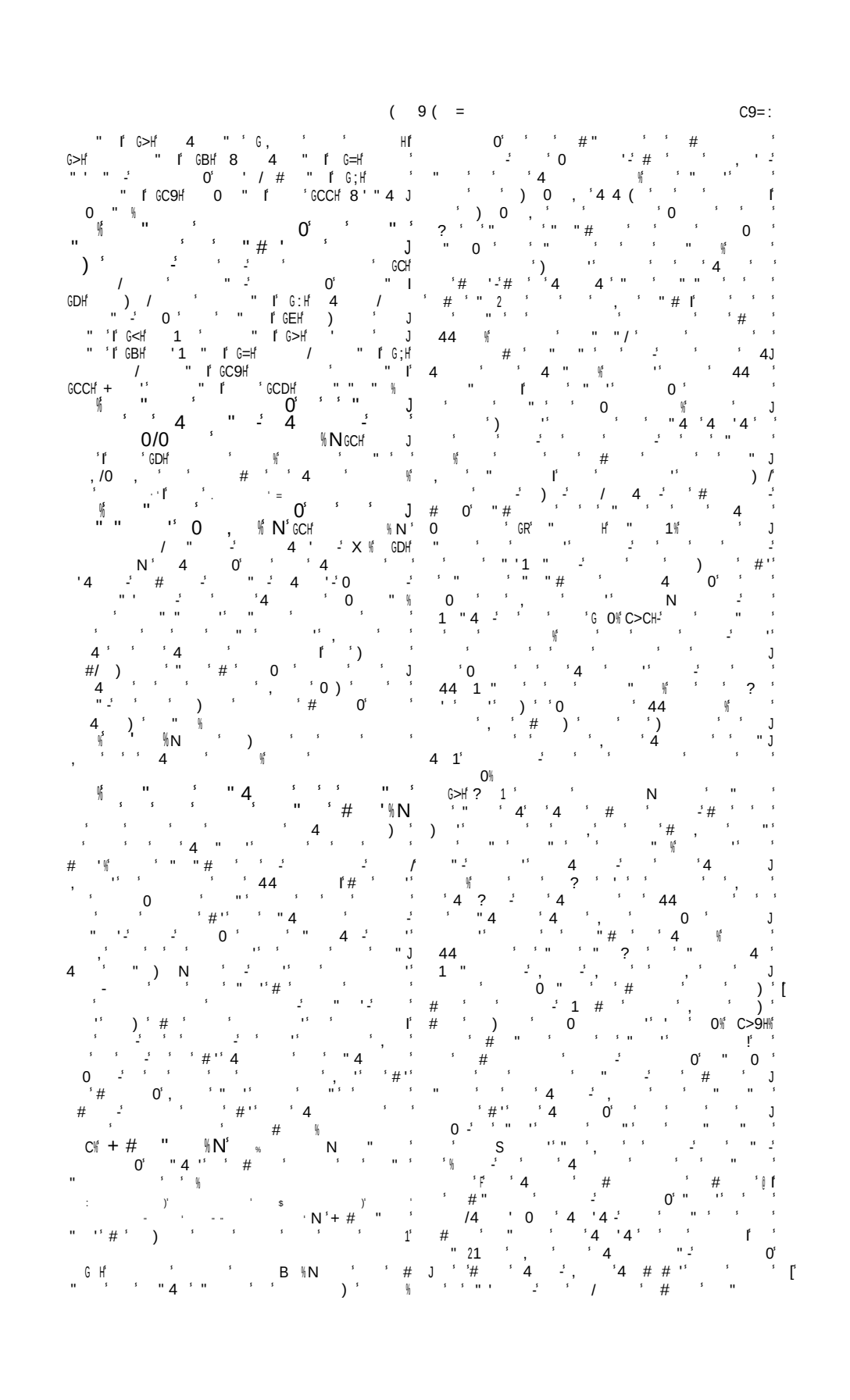


FIG. 160. Fibroma (Neuroma).

FIG. 161. Polypus of Nose.

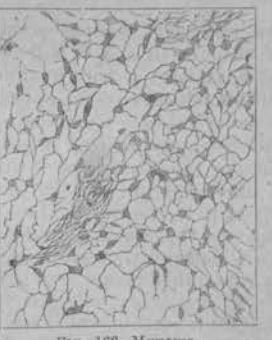


FIG. 162. Myxoma.

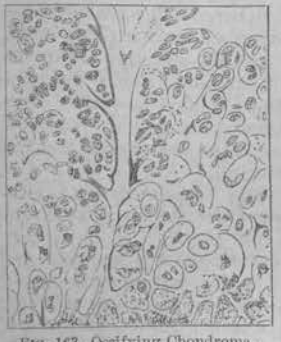


FIG. 163. Ossifying Chondroma.

FIG. 164. Enchondroma (of Jaw).

FIG. 165. Enchondroma (of Orbit).

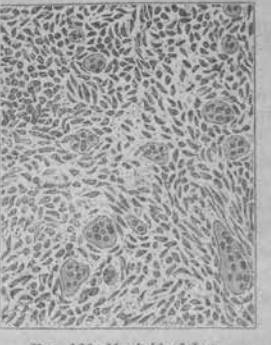


FIG. 166. Myeloid of Jaw.

FIG. 167. Large Round-celled Sarcoma.

FIG. 169. Oval-celled Sarcoma.

FIG. 168. Small Round-celled Sarcoma.

FIG. 170. Lymphoma.

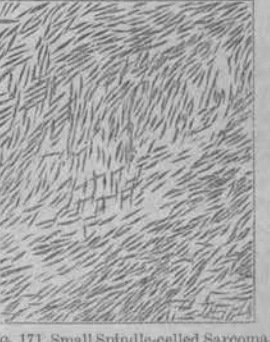


FIG. 171. Small Spindle-celled Sarcoma.

FIG. 172. Alveolar Sarcoma.

FIG. 173. Mixed Sarcoma.

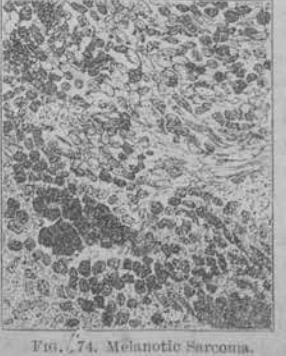
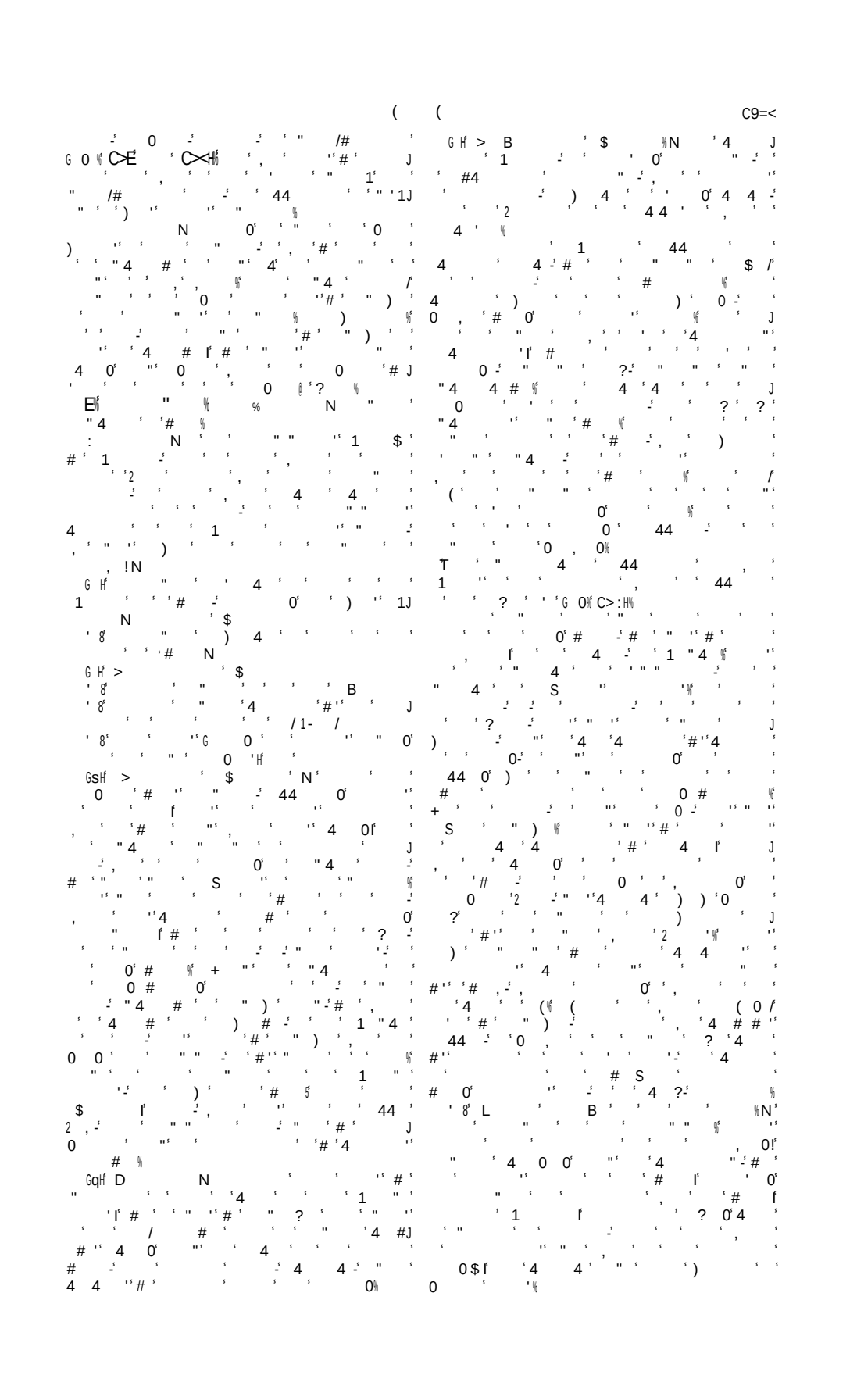


FIG. 174. Melanotic Sarcoma.

FIG. 175. Large Spindle-celled Sarcoma.

Drawings illustrating a Series of Tumours of the Connective-tissue Type. All drawn to the same scale (× 87 diameters).



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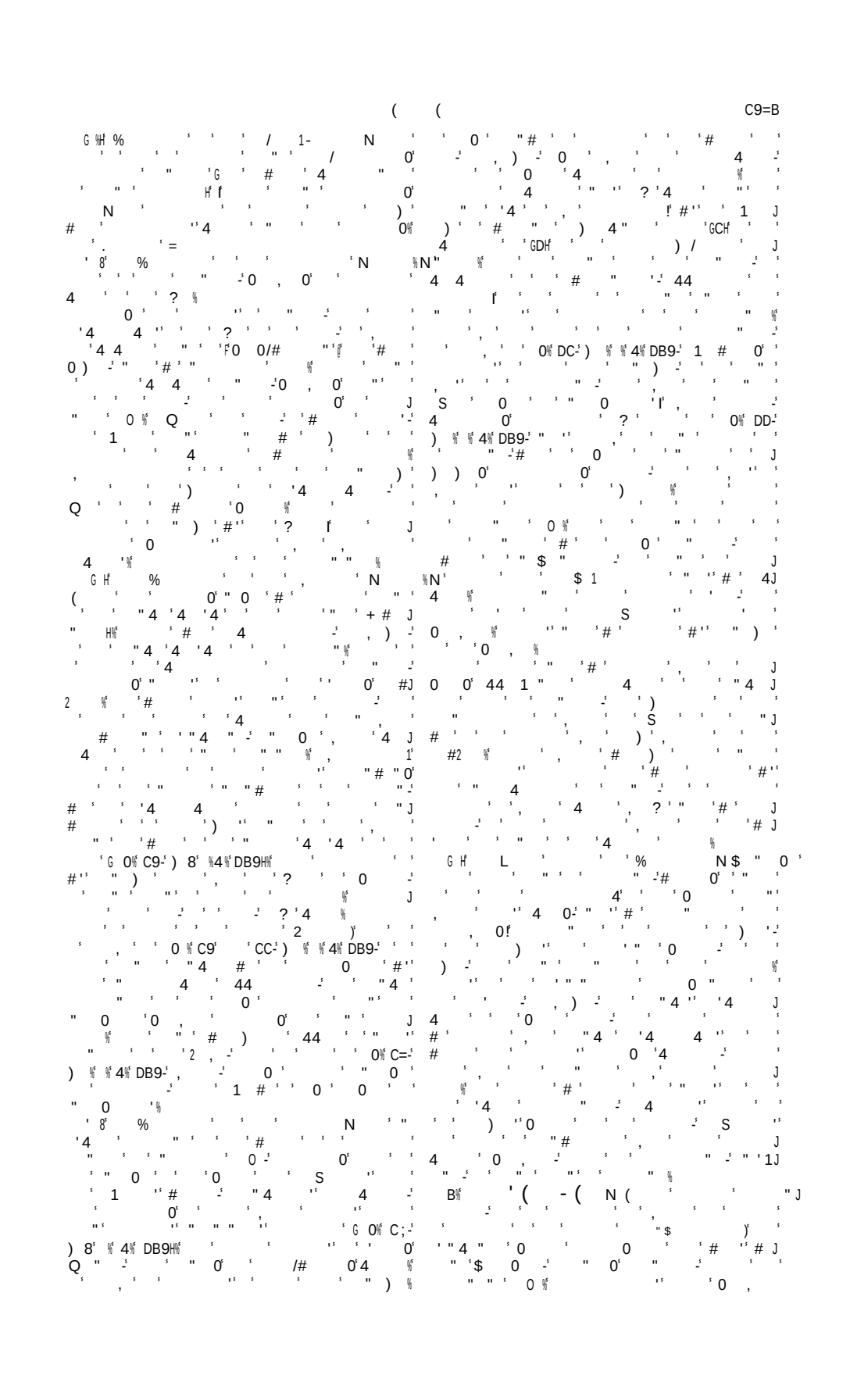

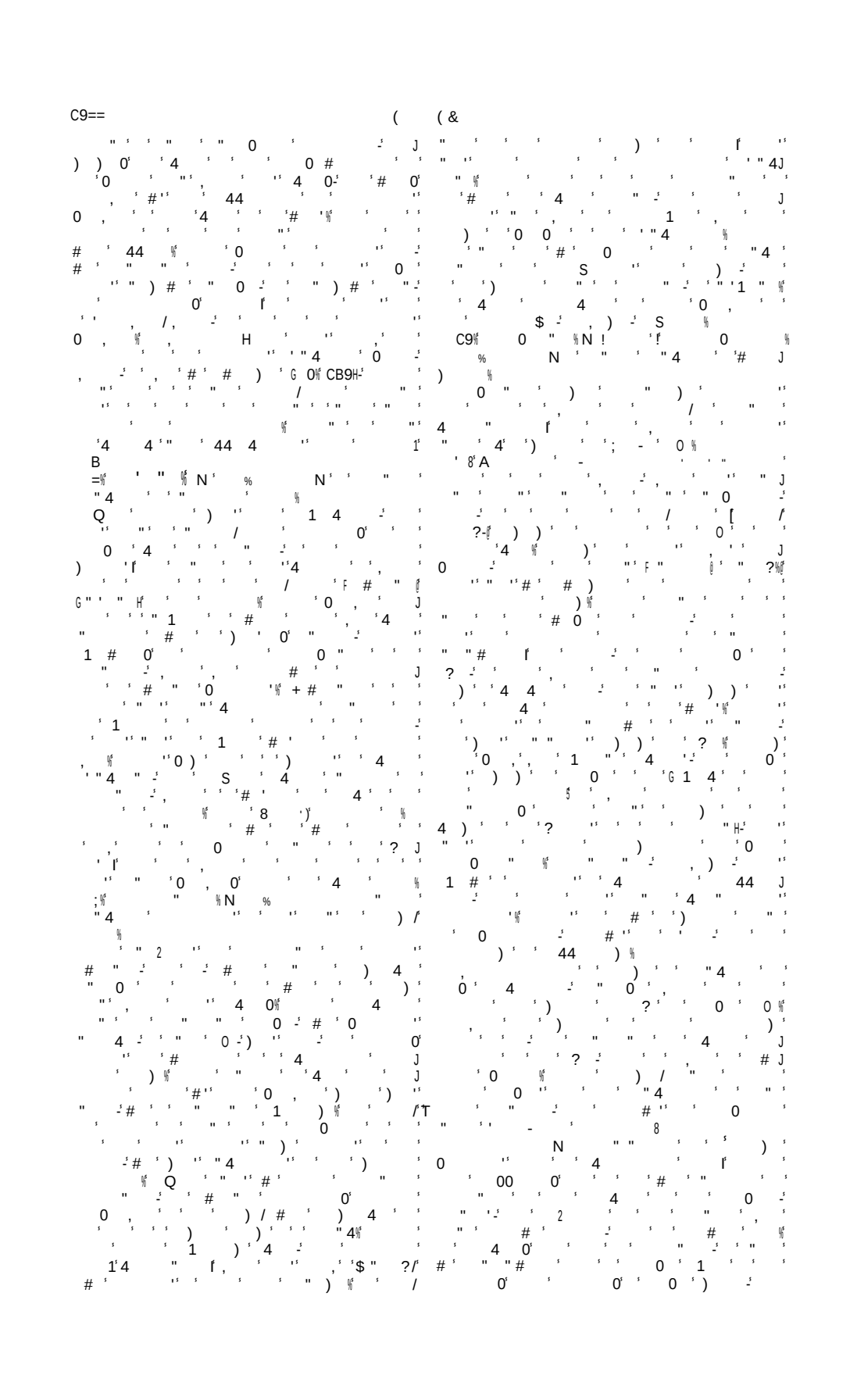

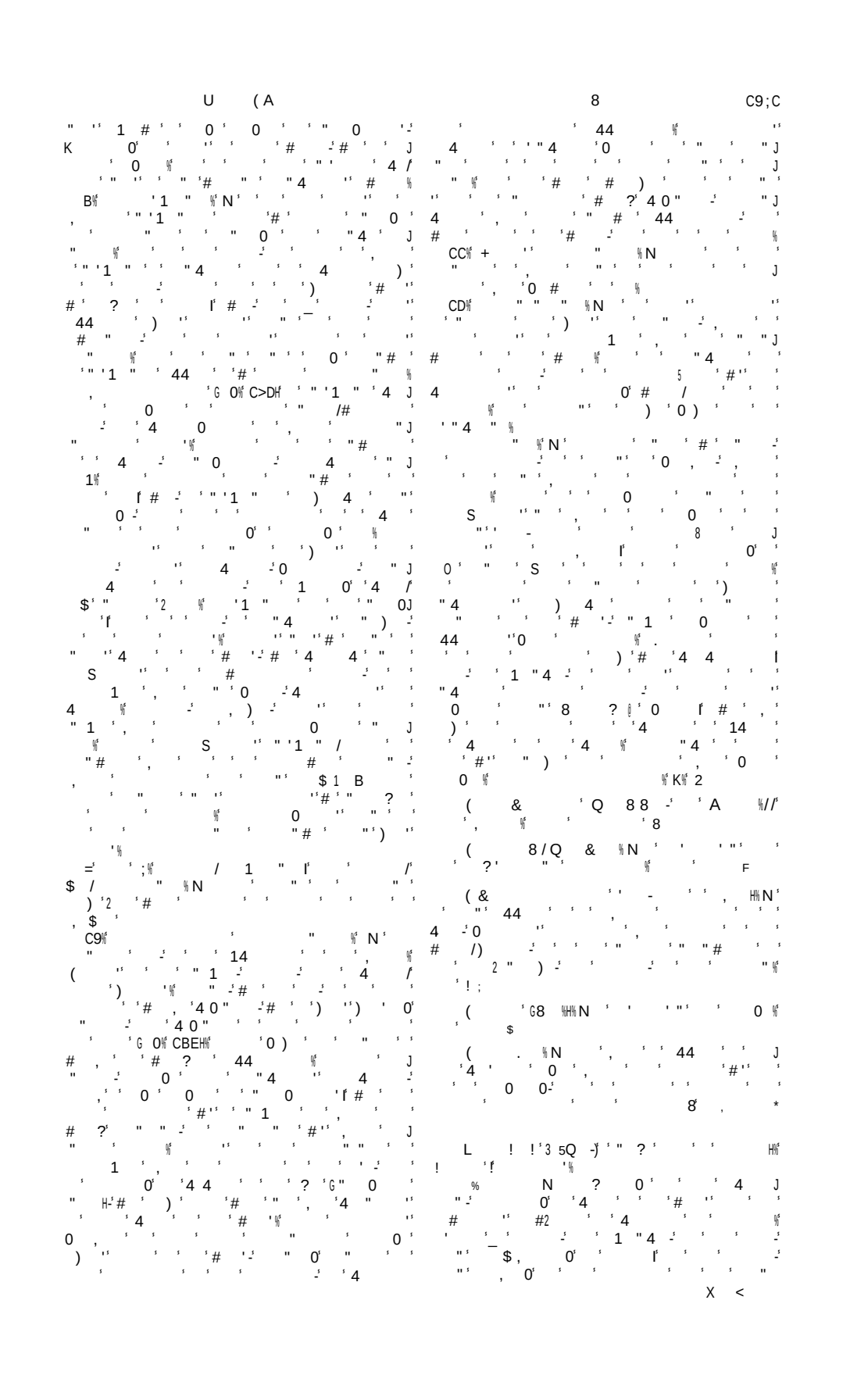

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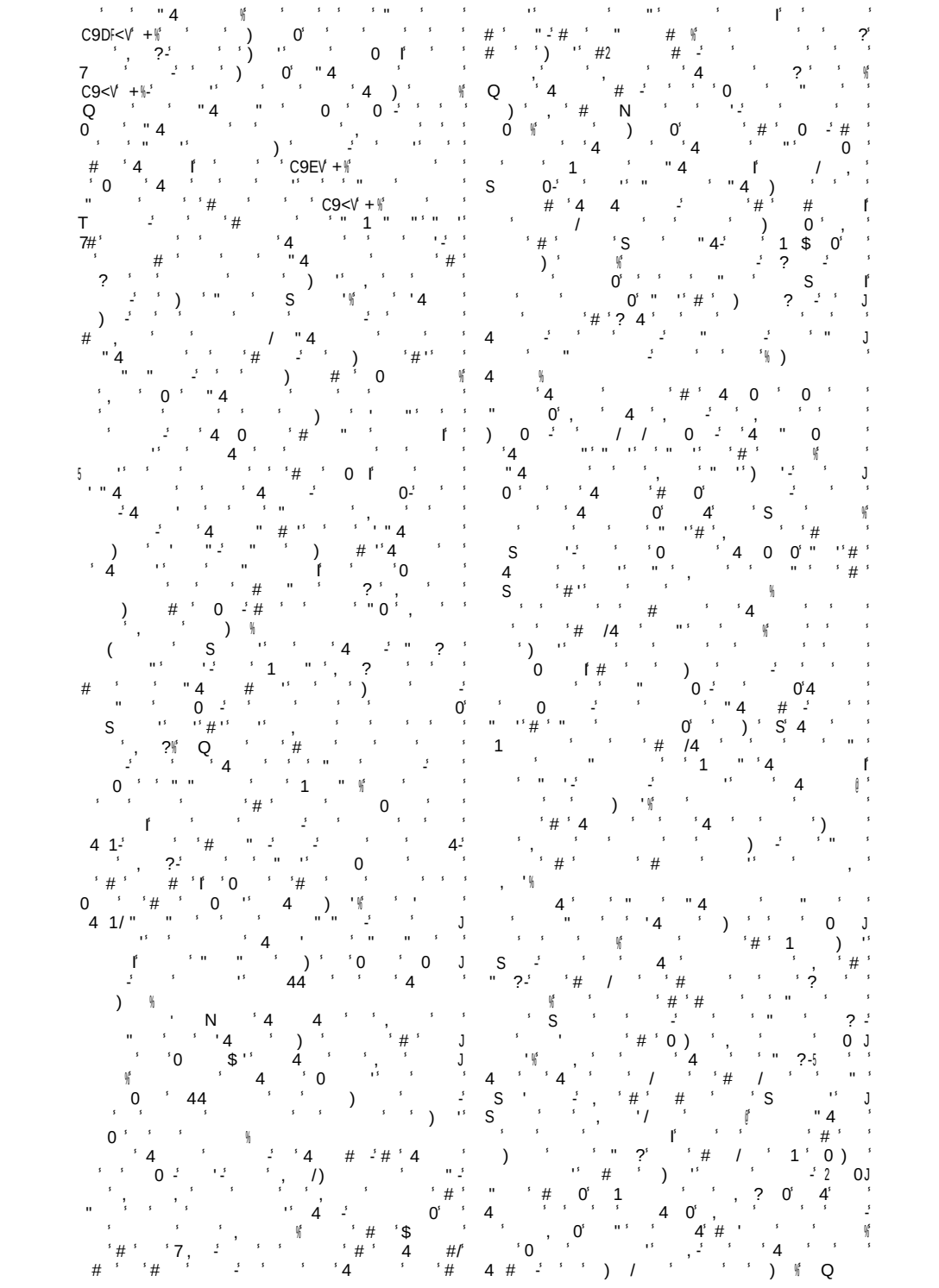

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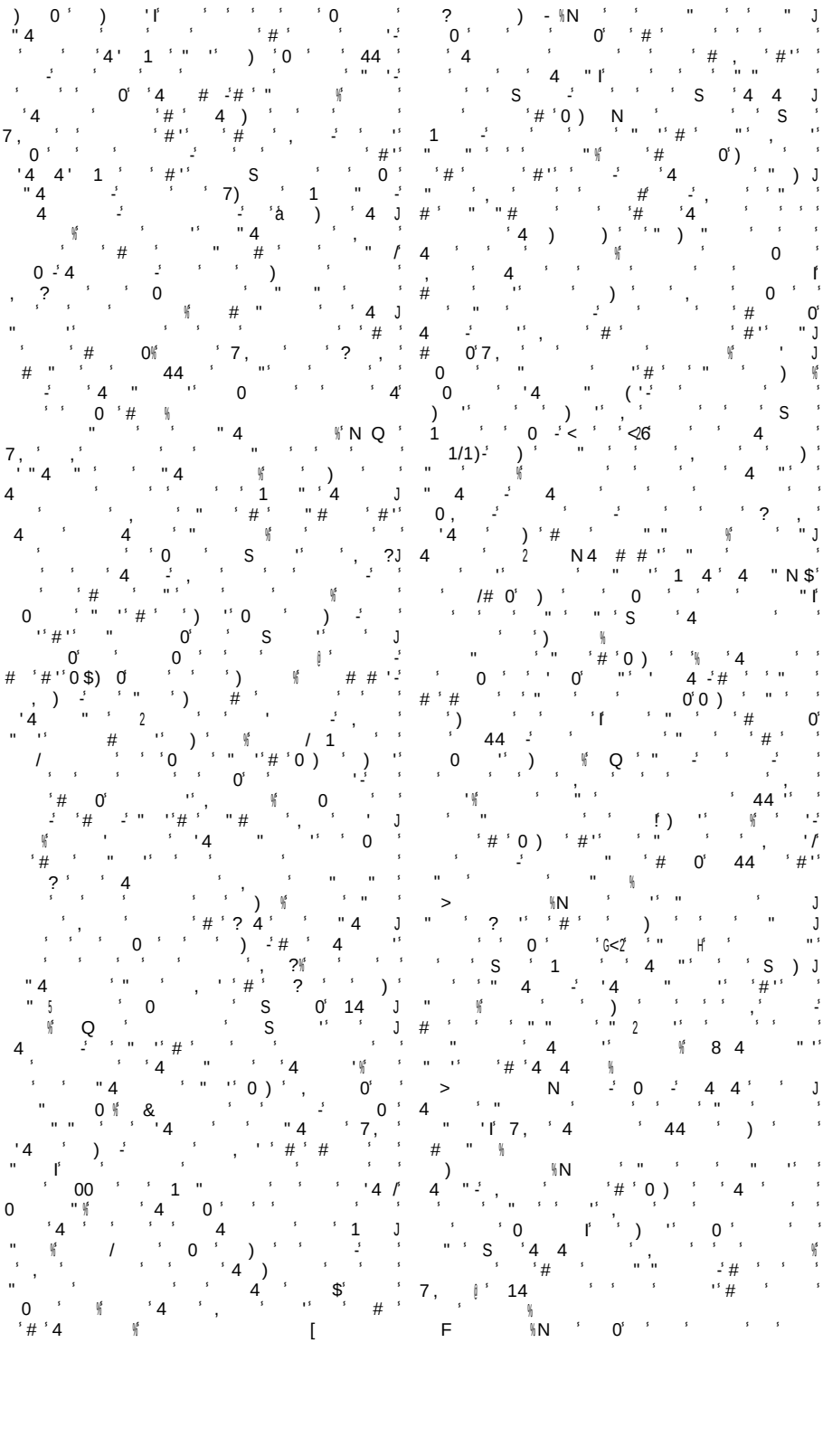

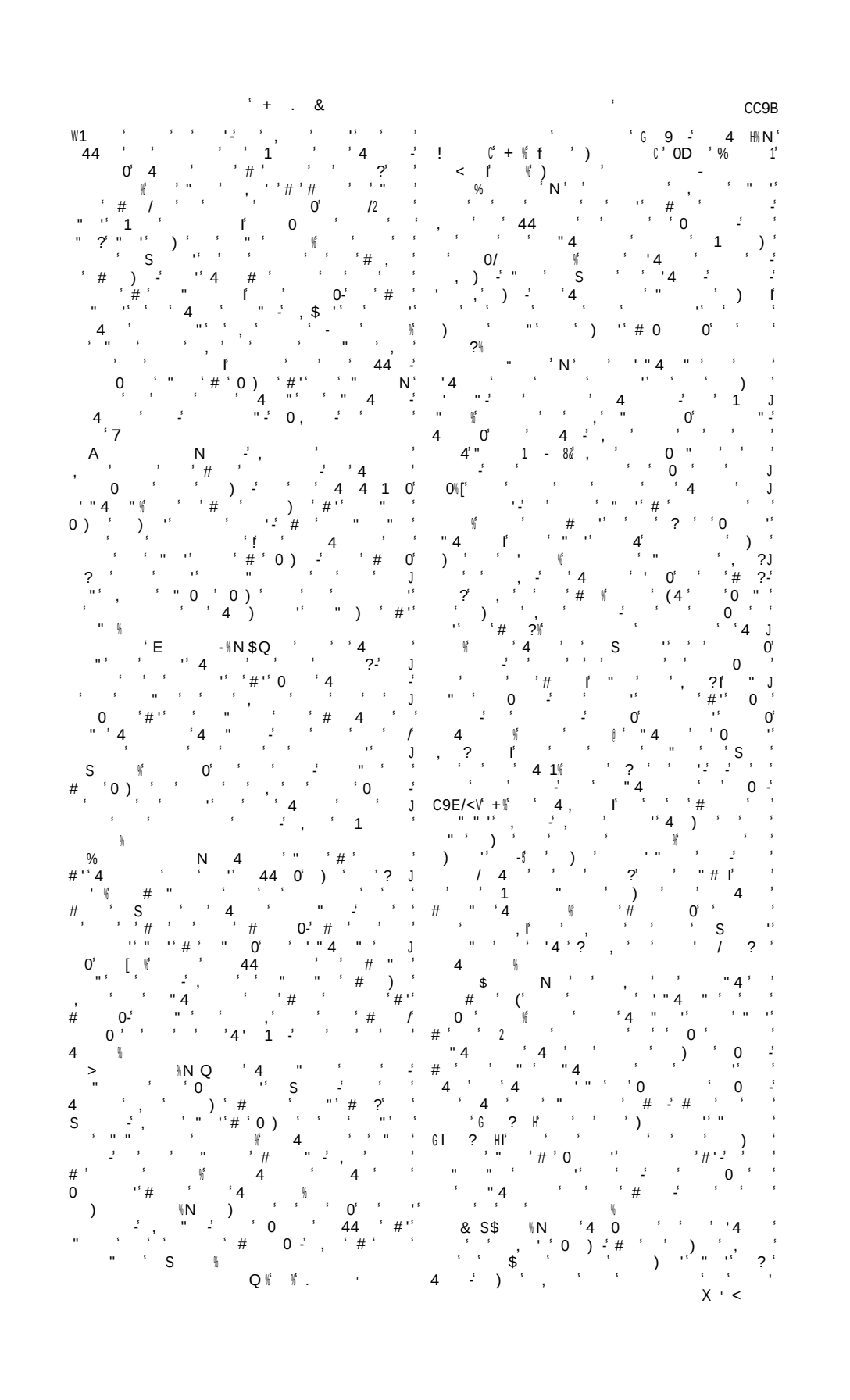

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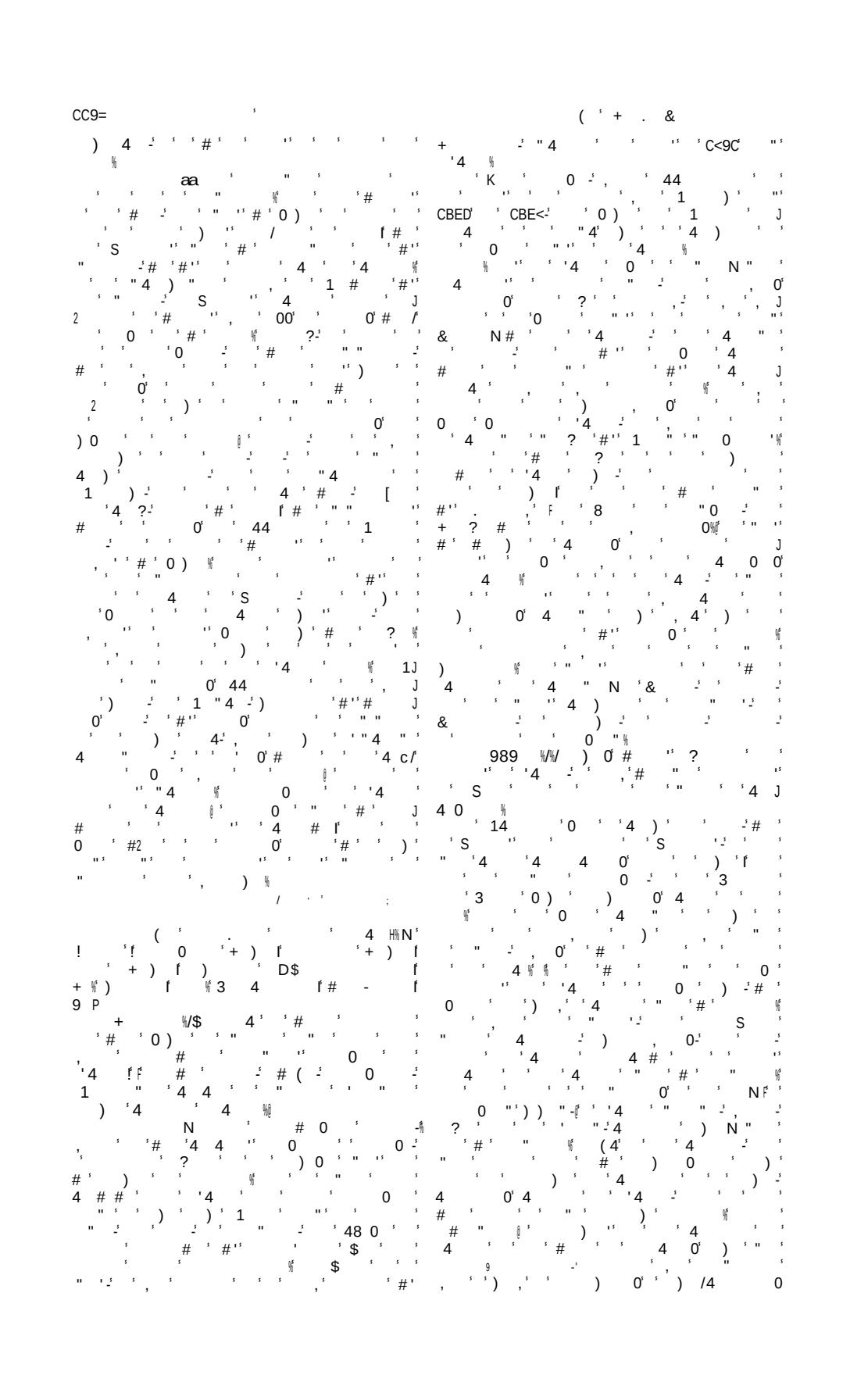

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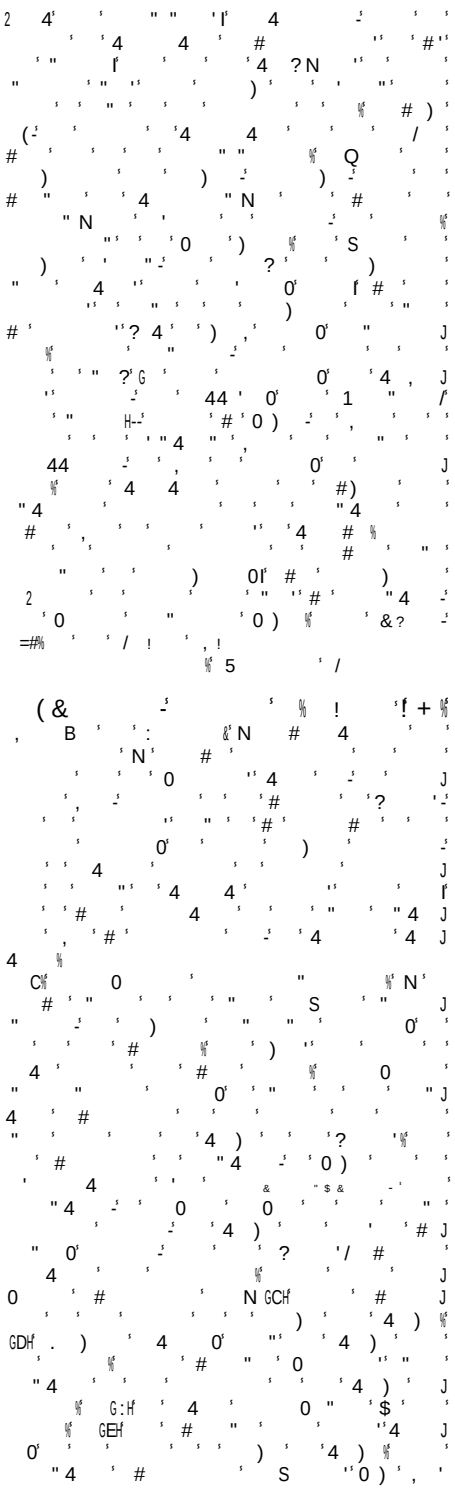

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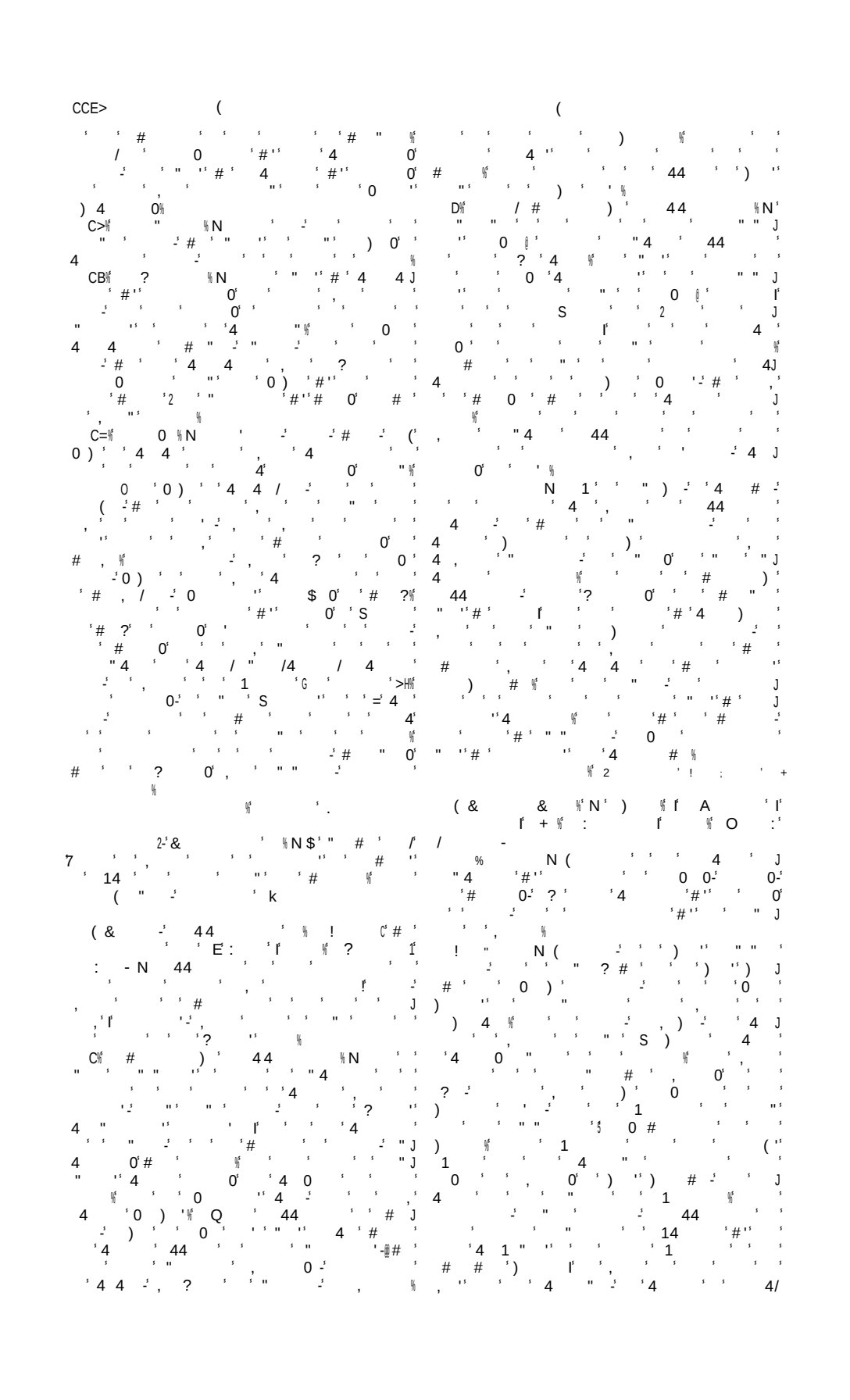

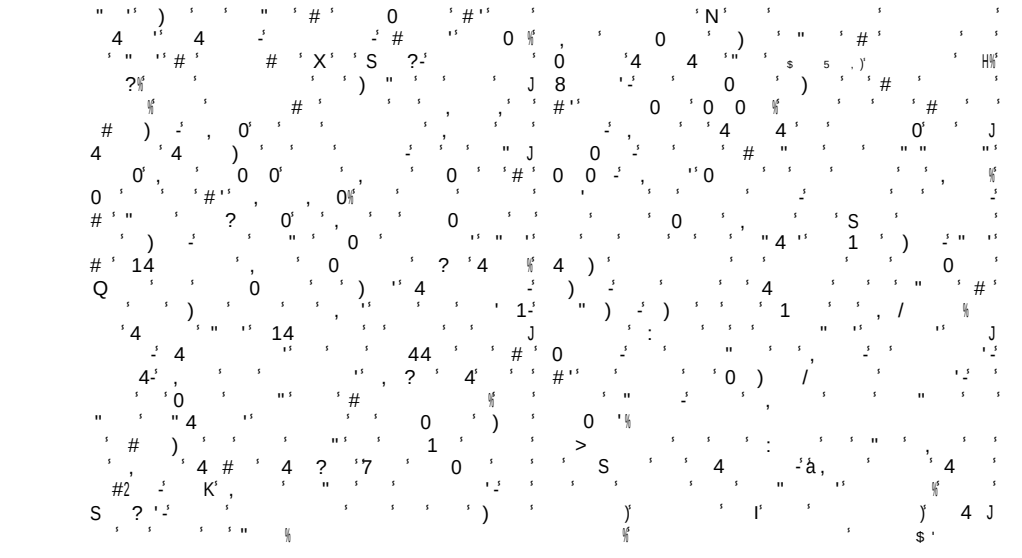

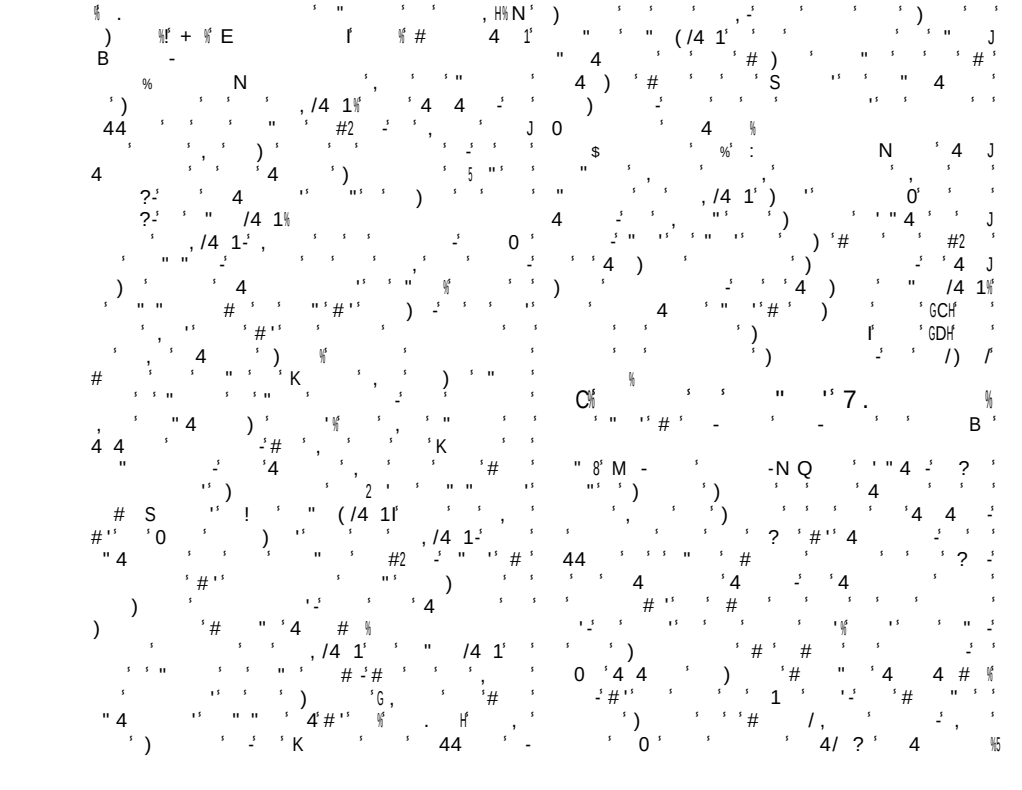

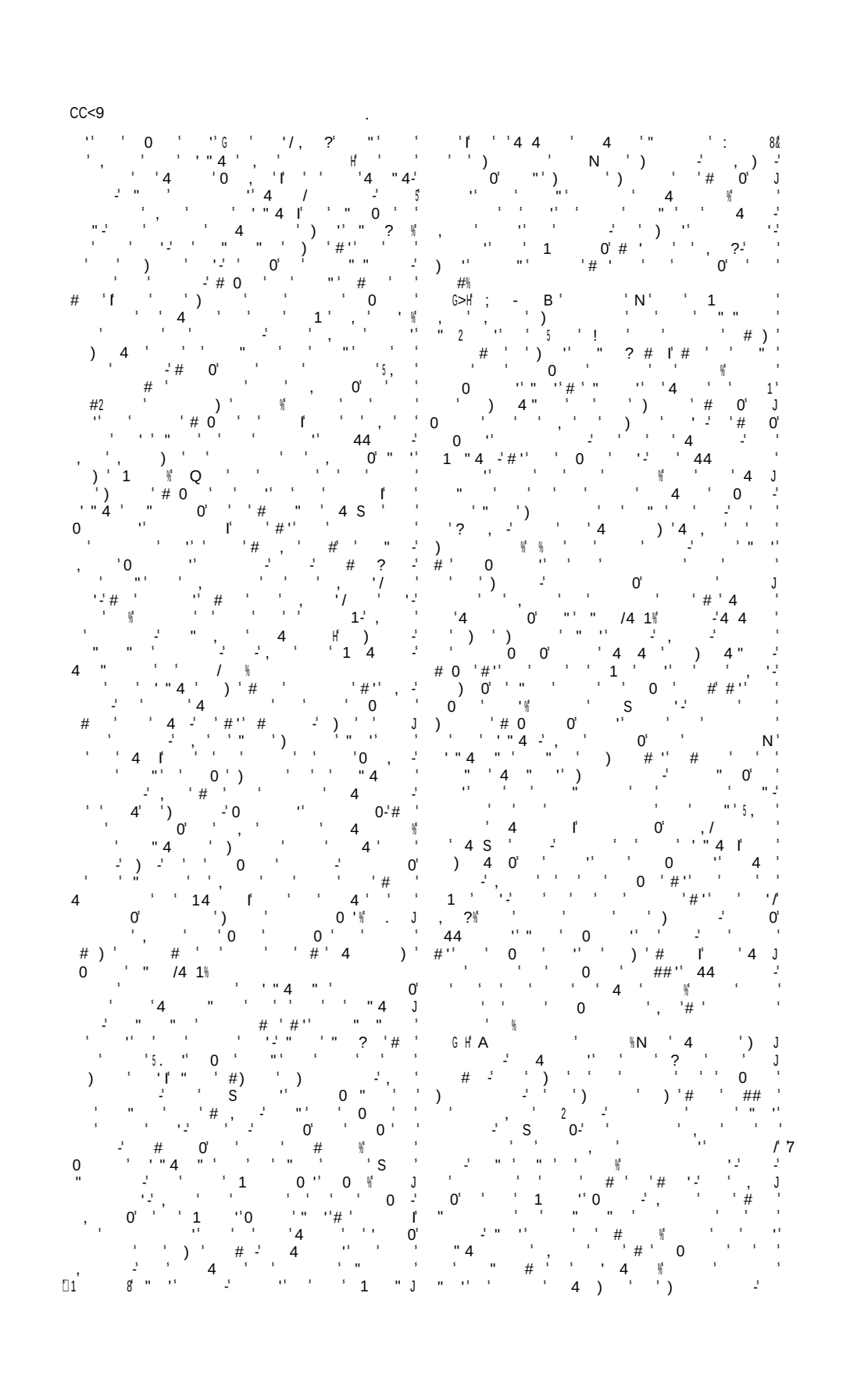

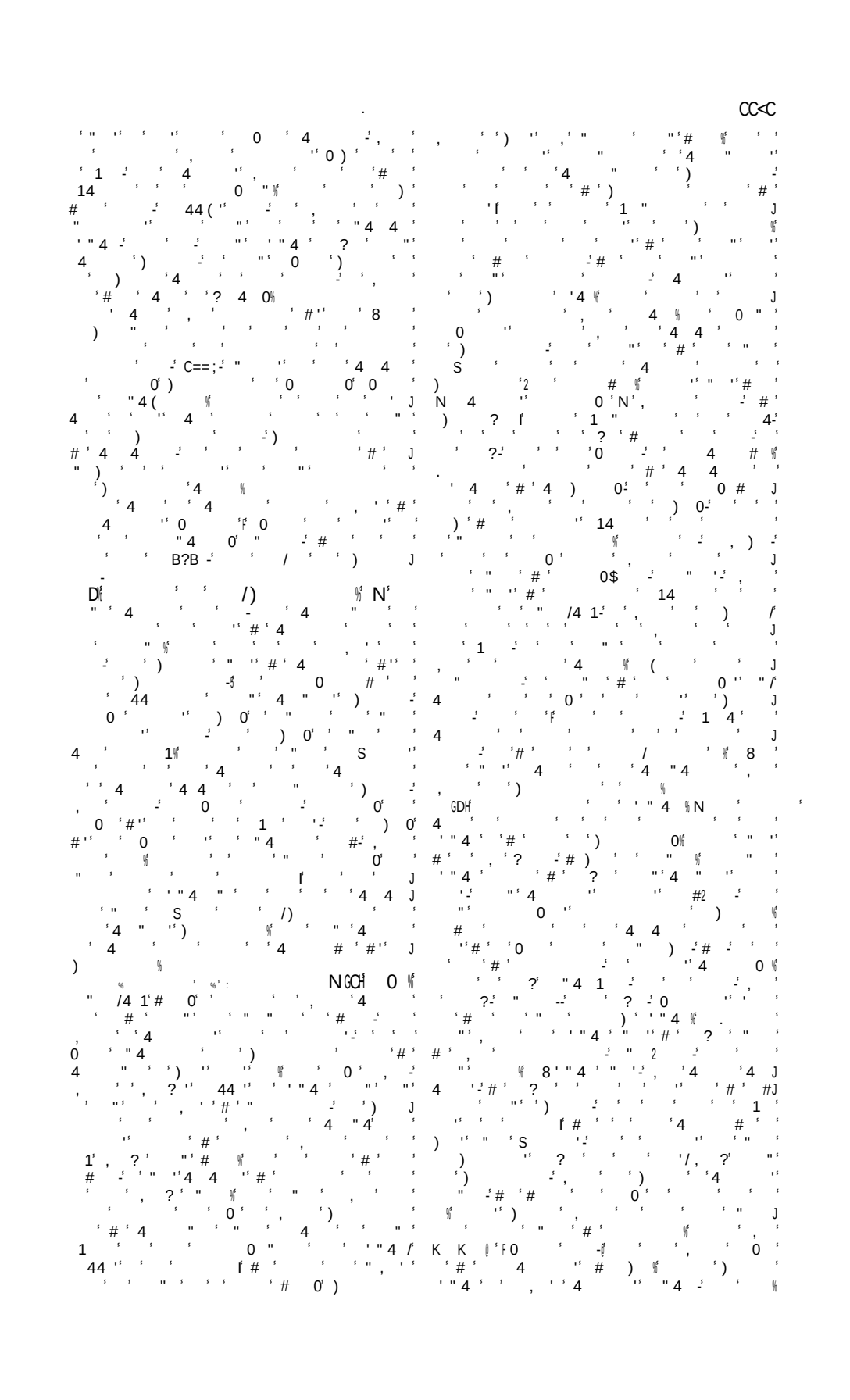

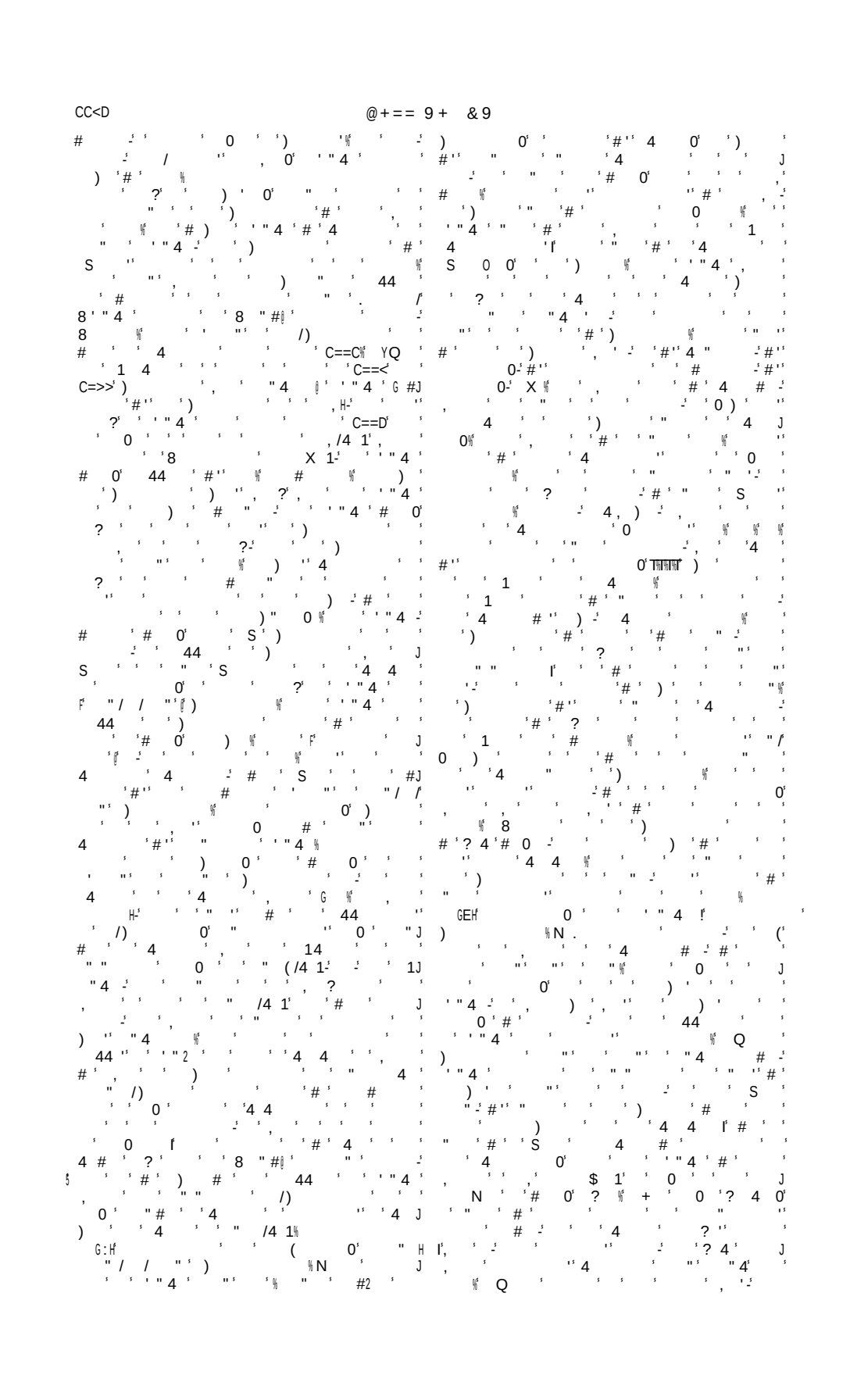

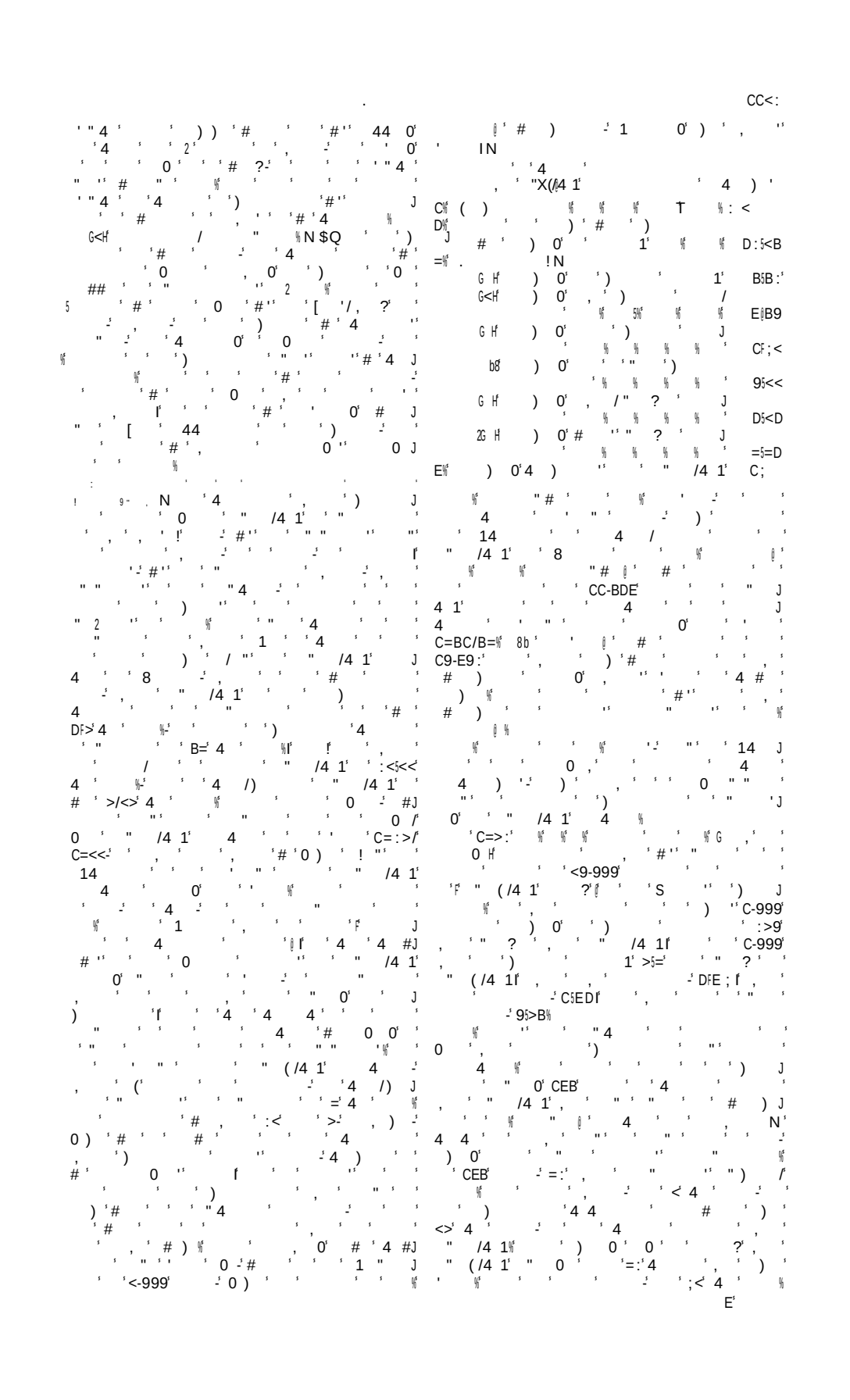

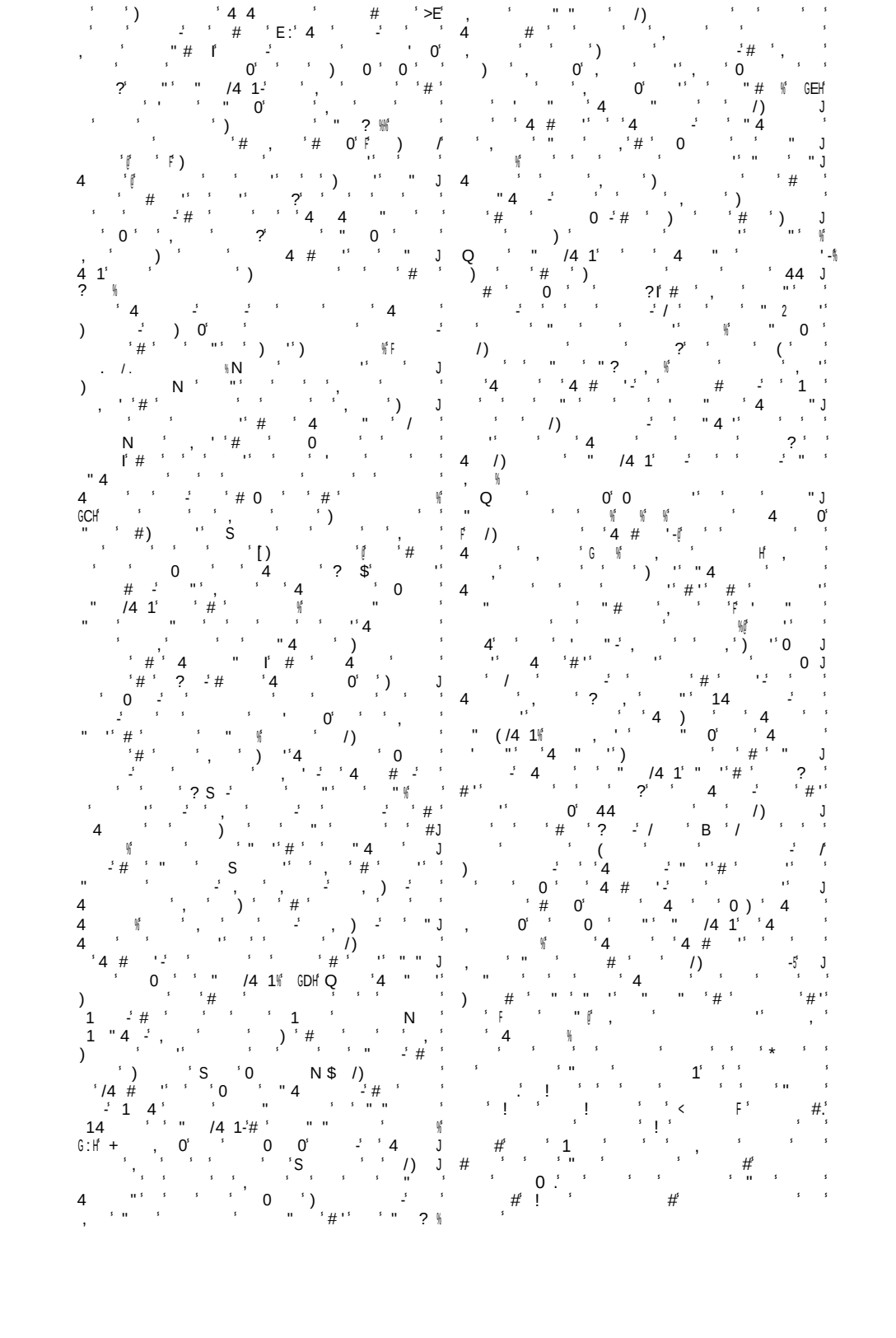

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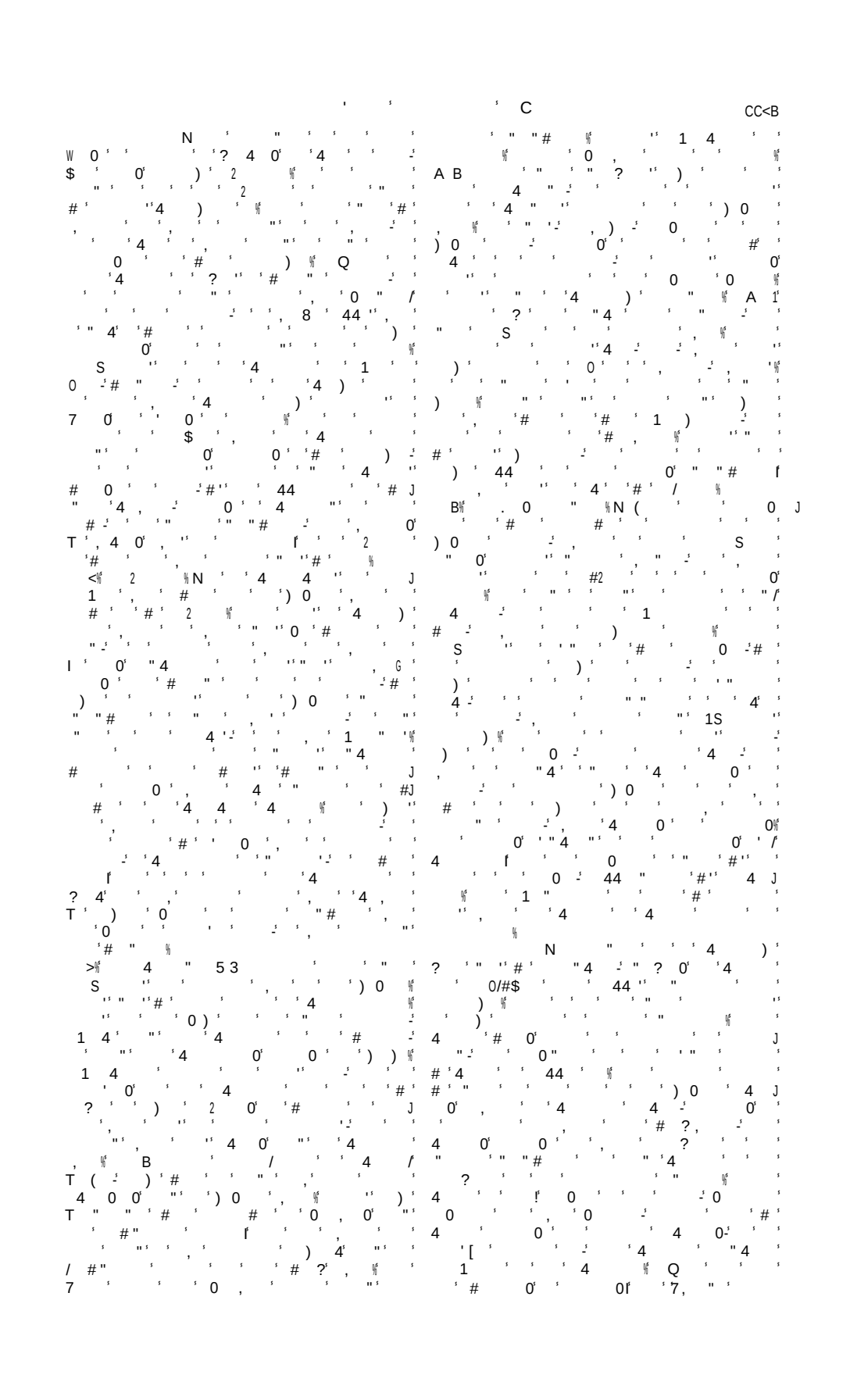

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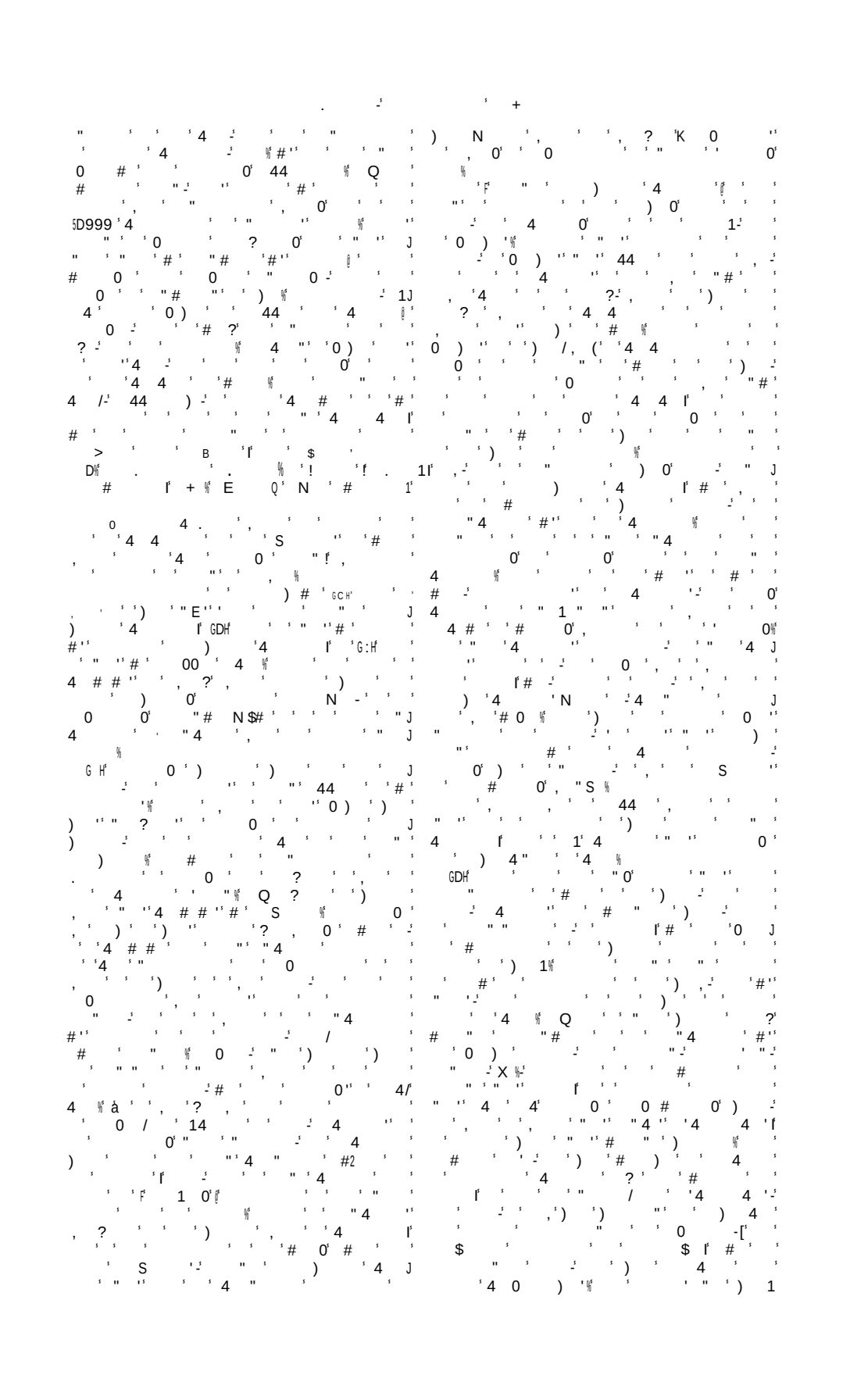

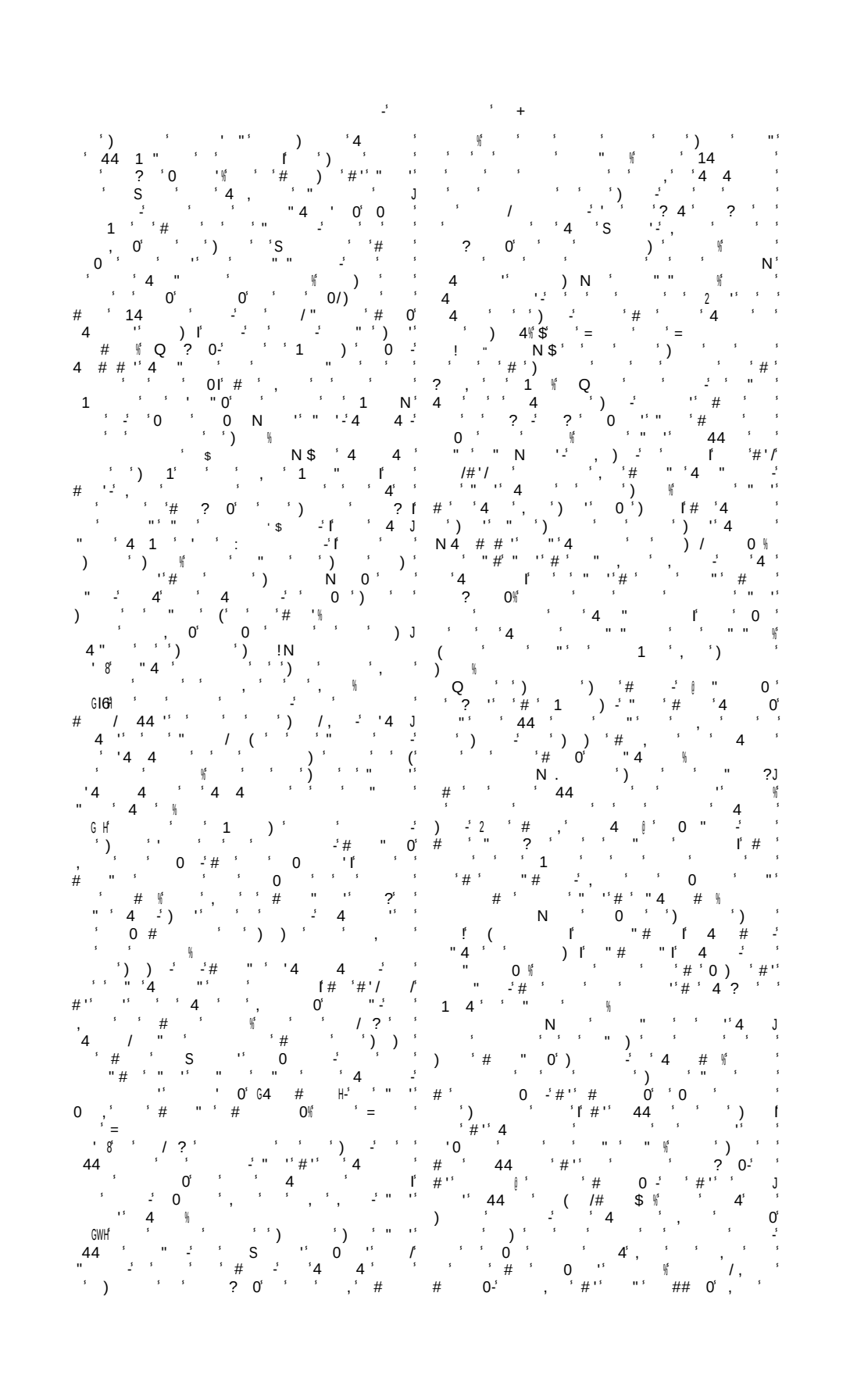

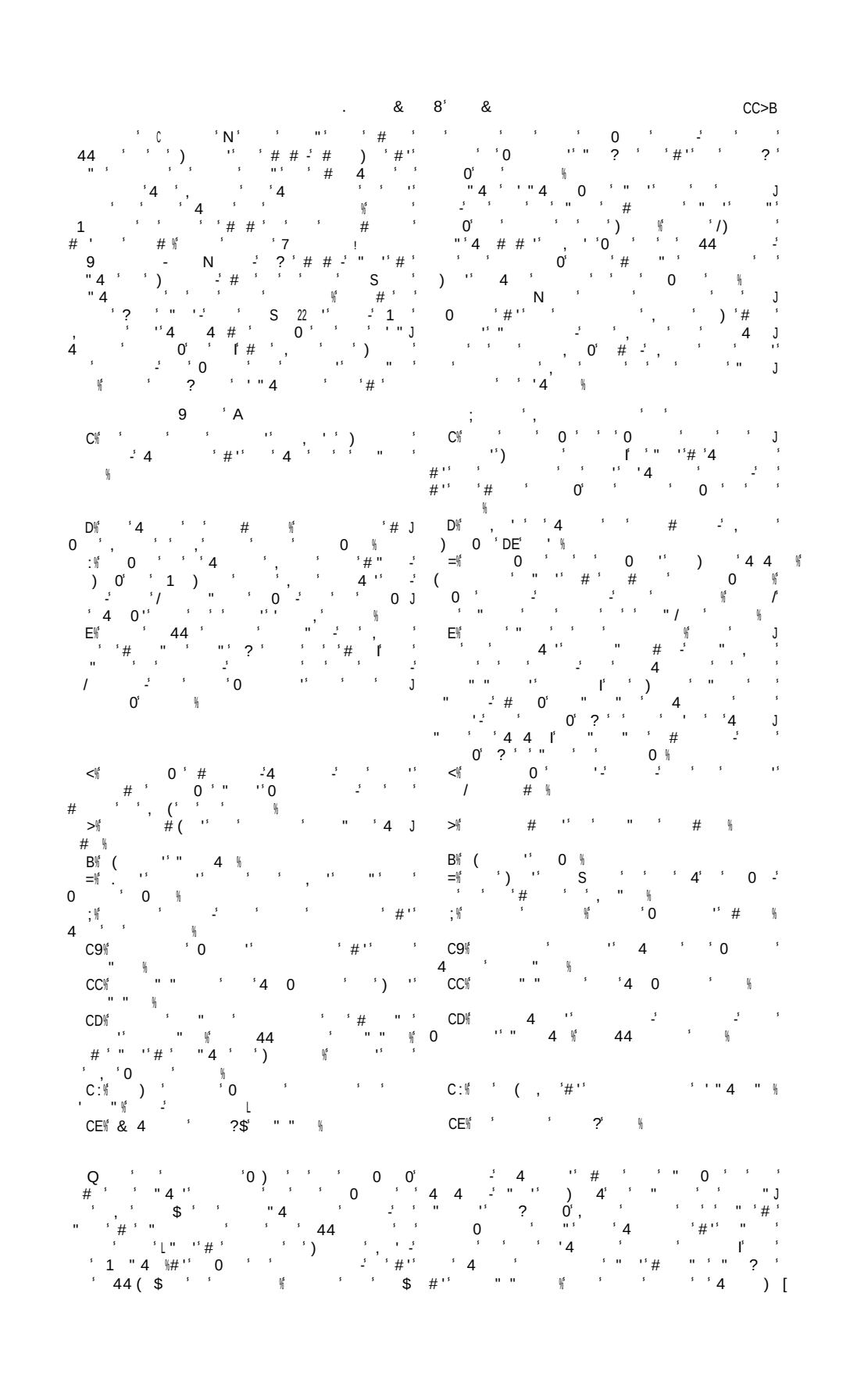

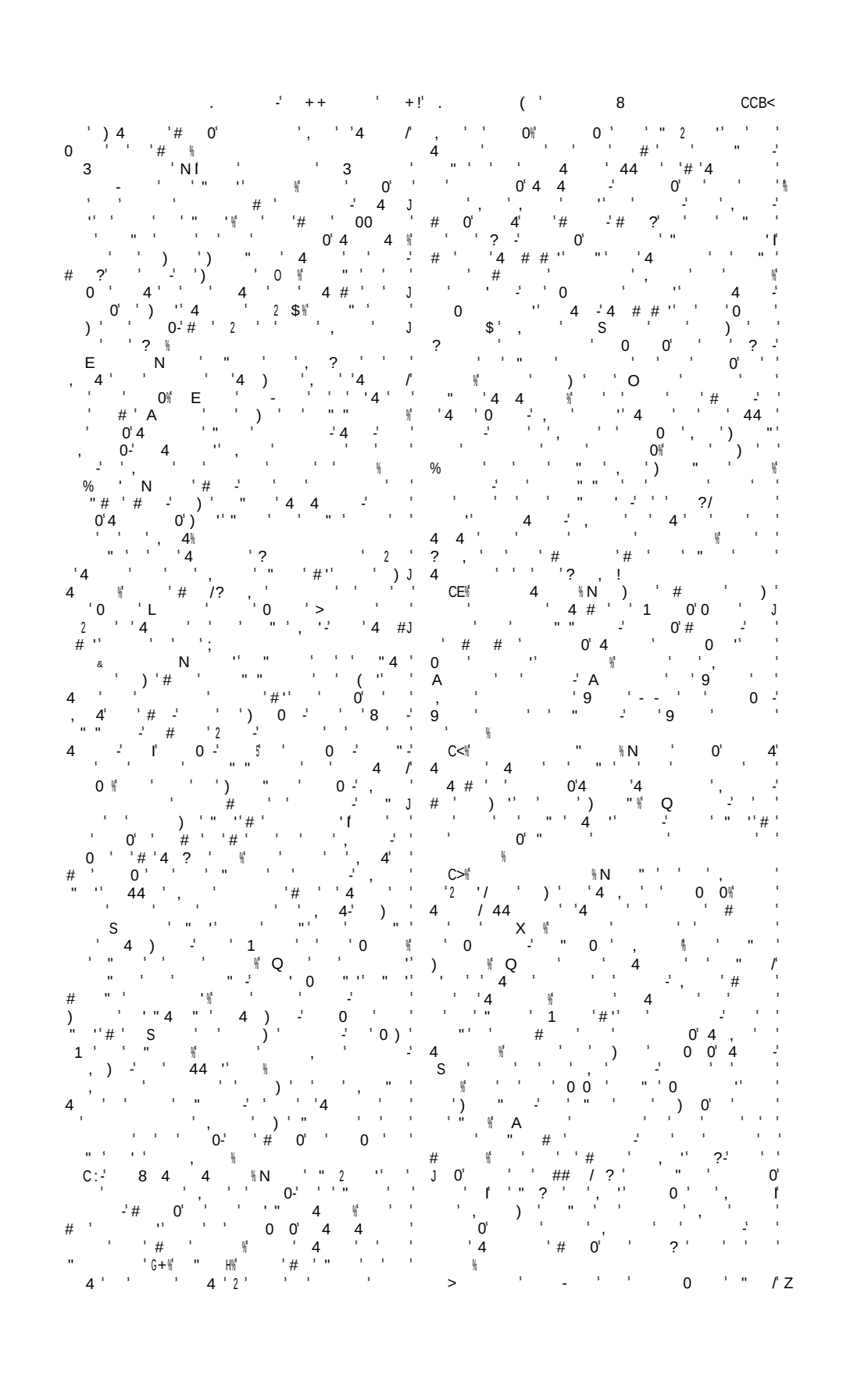

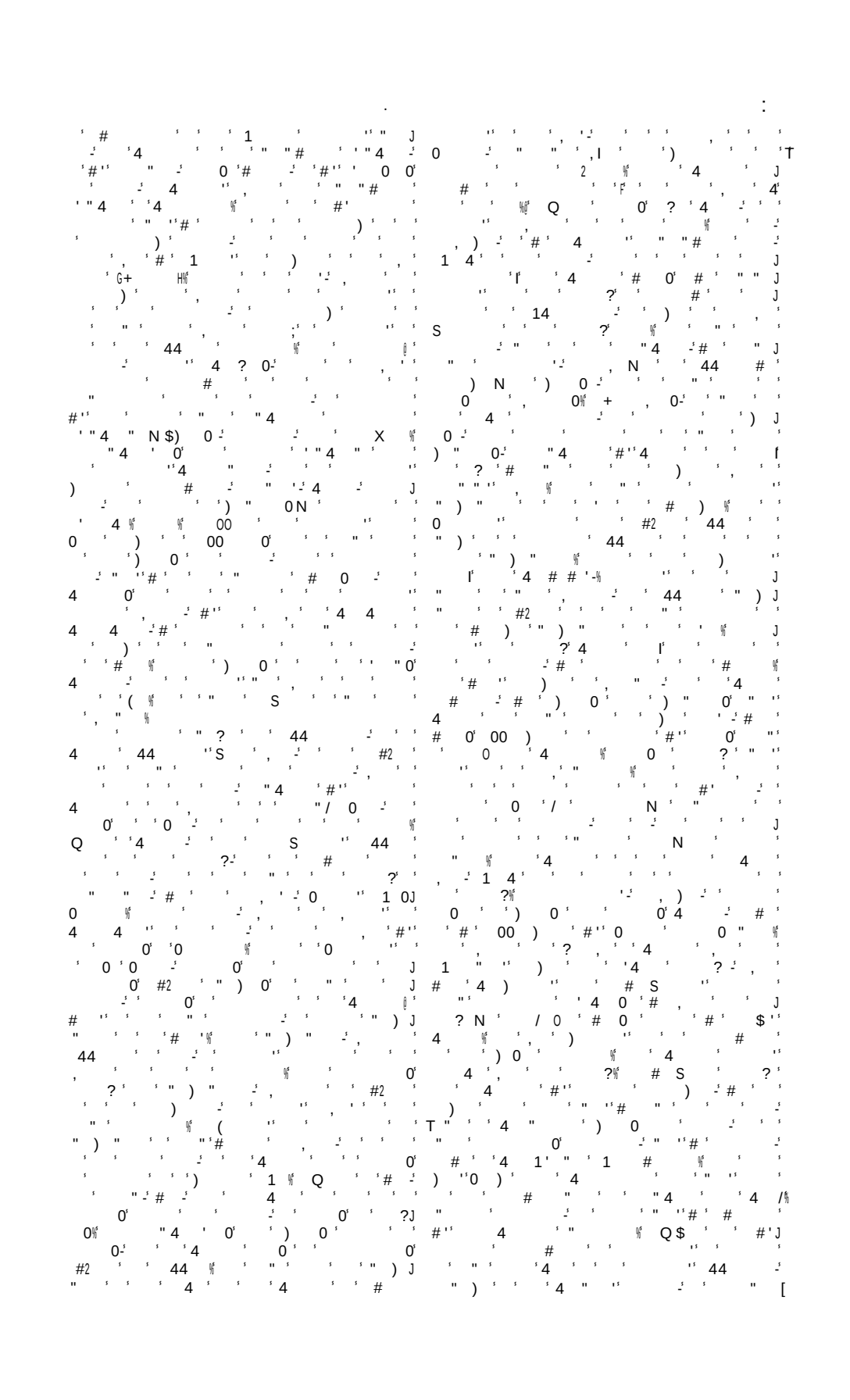

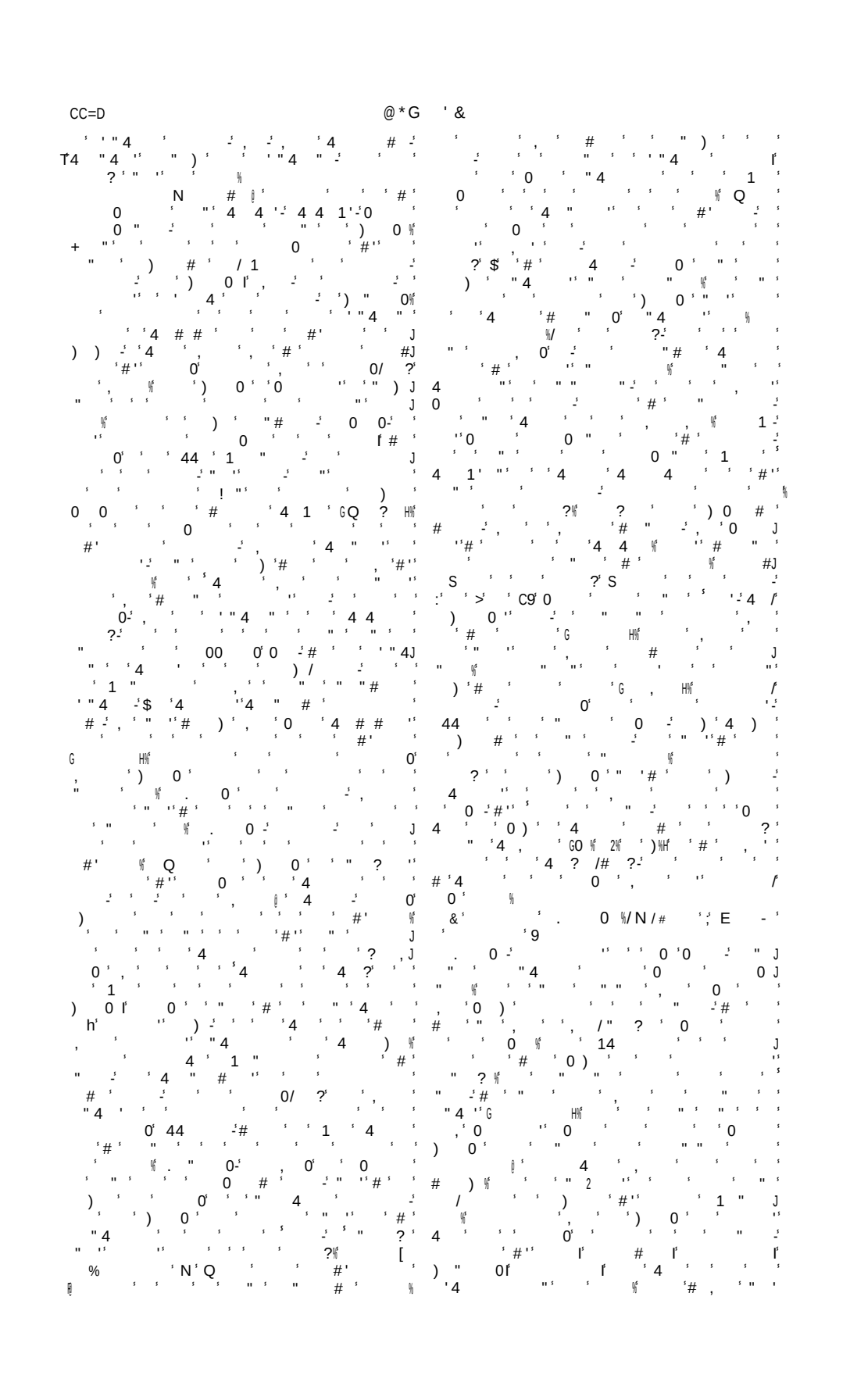

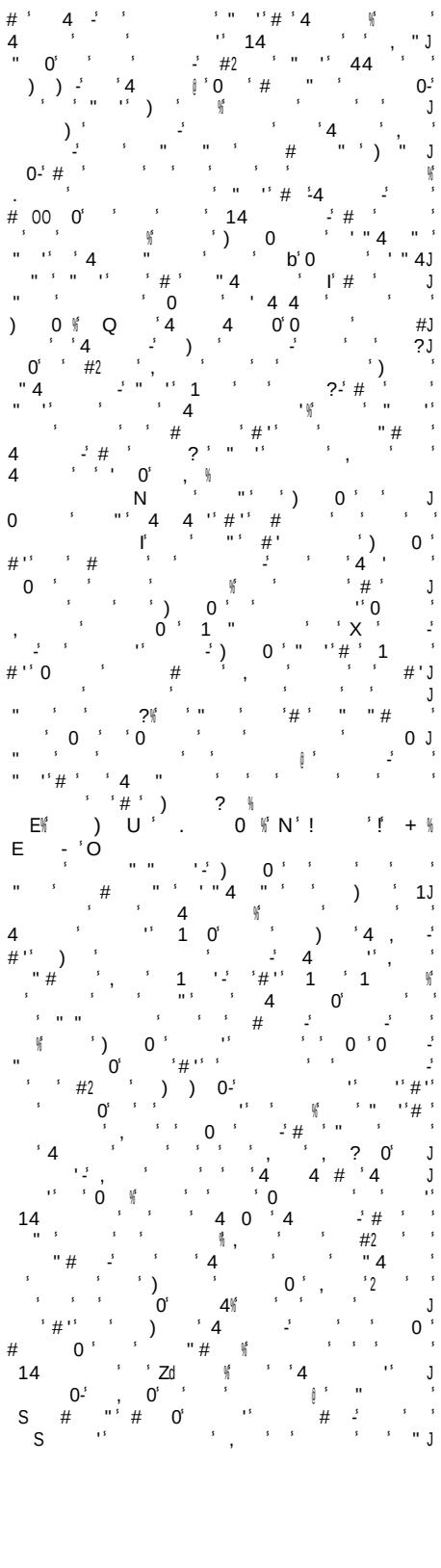

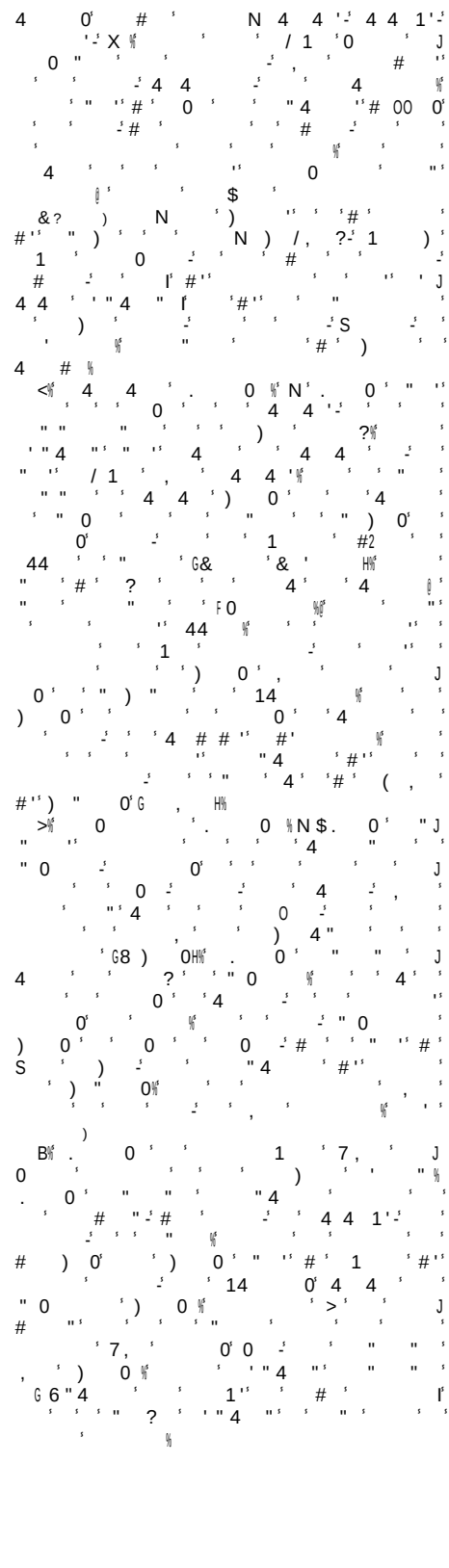

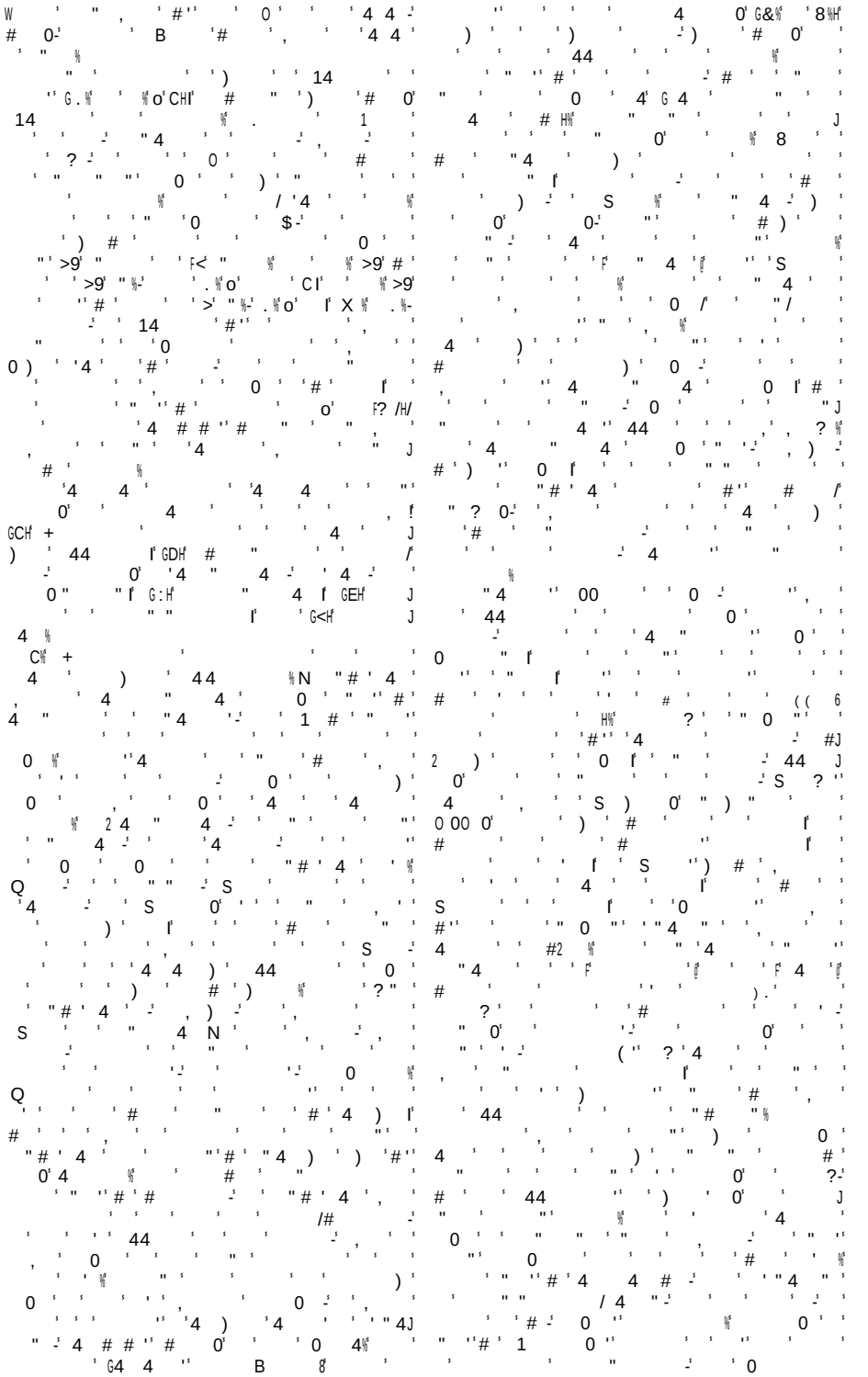

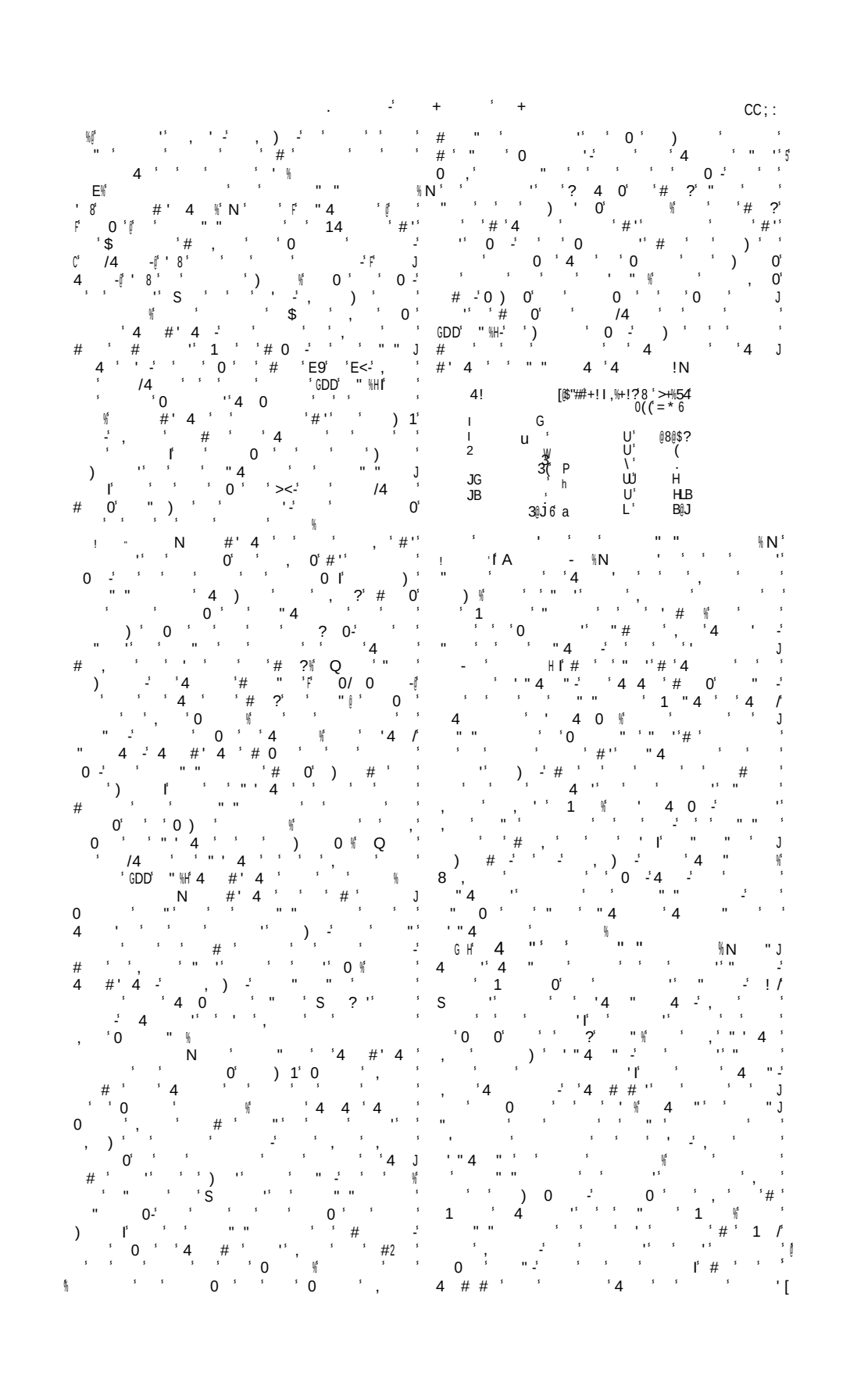

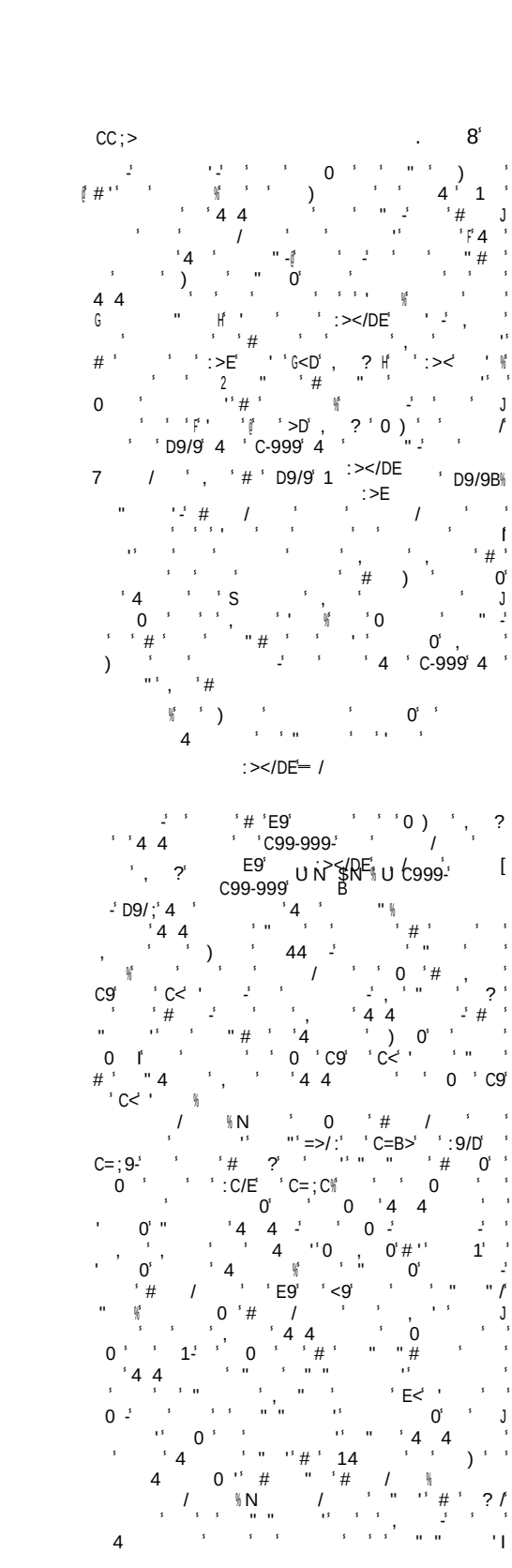

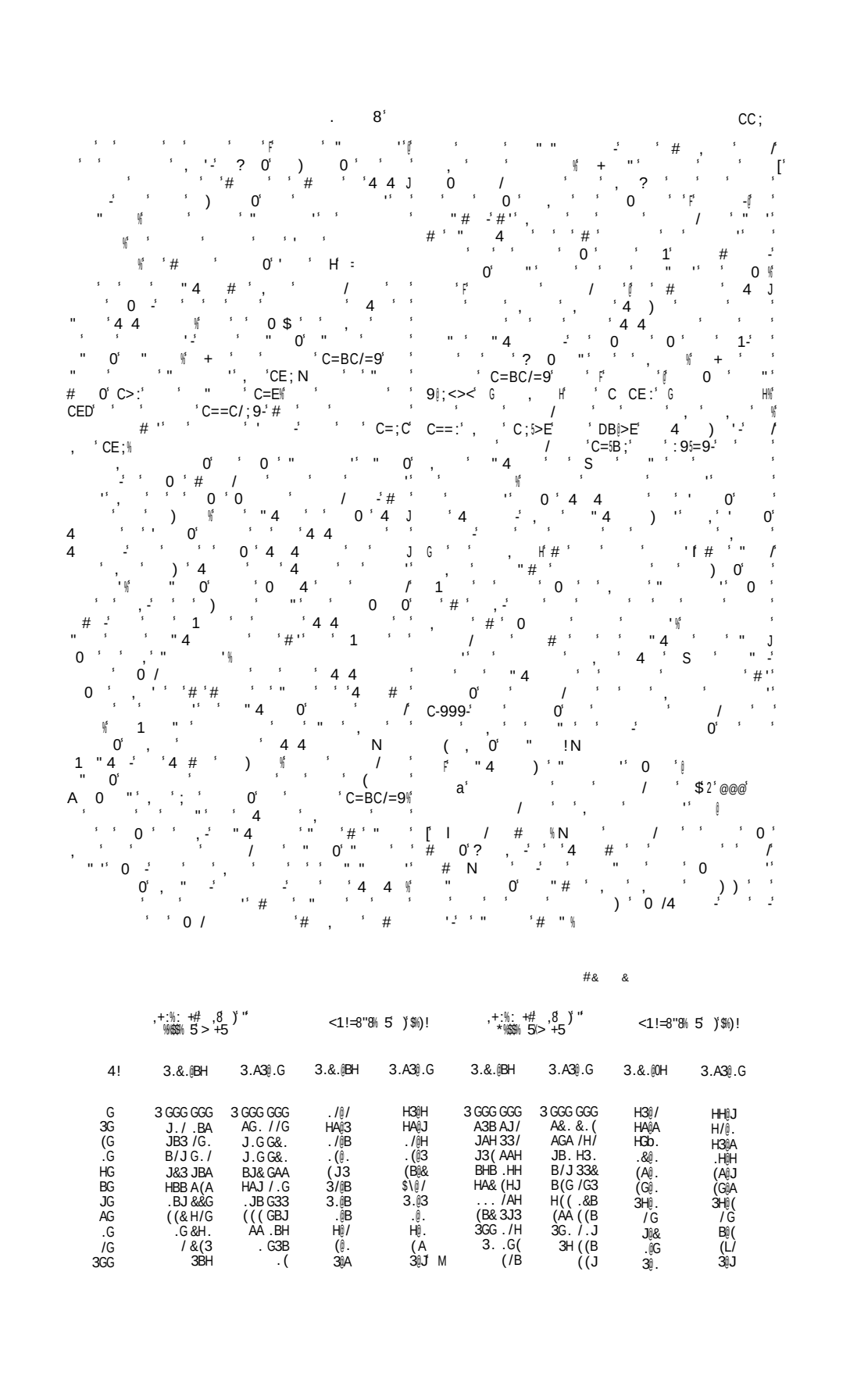

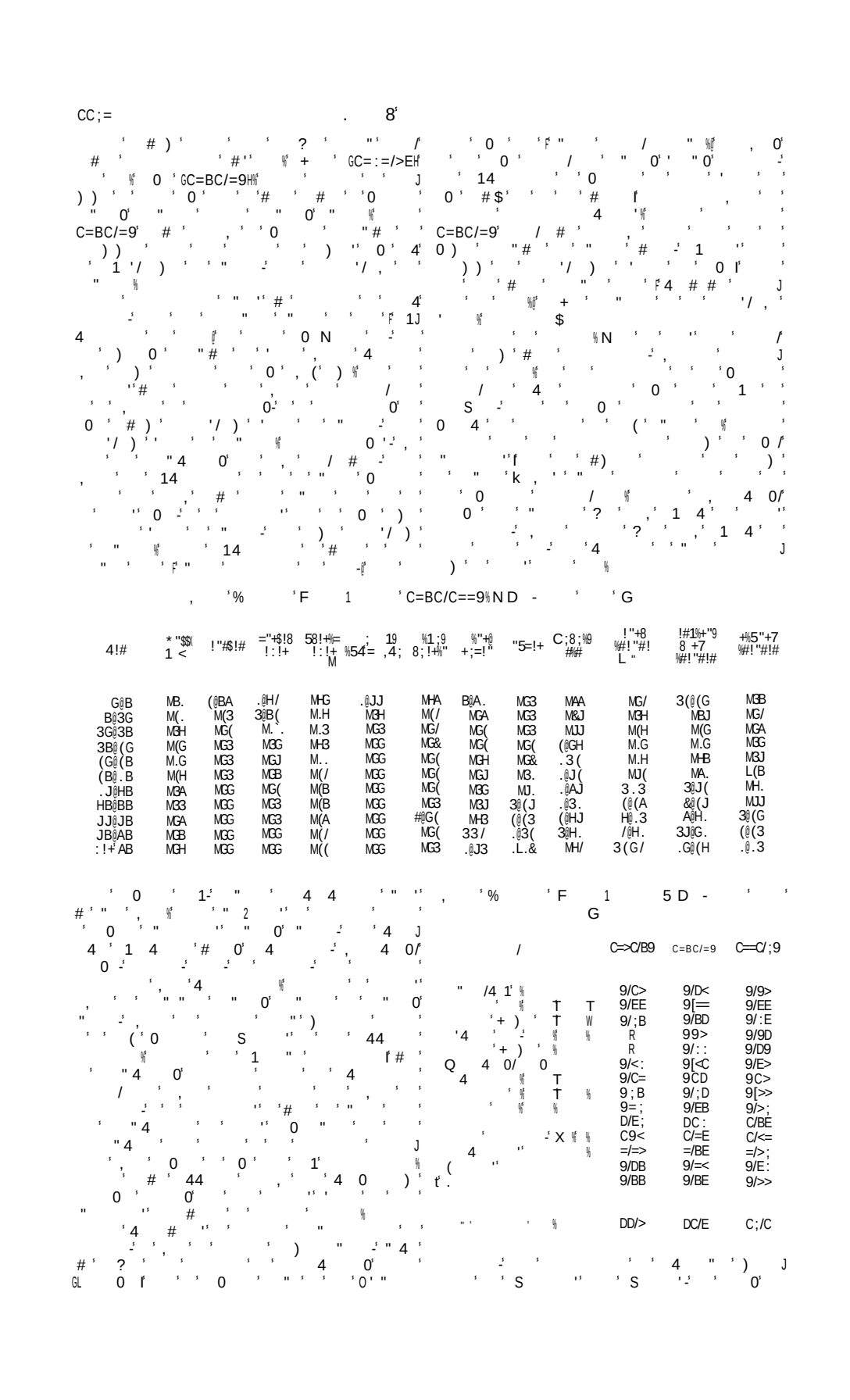

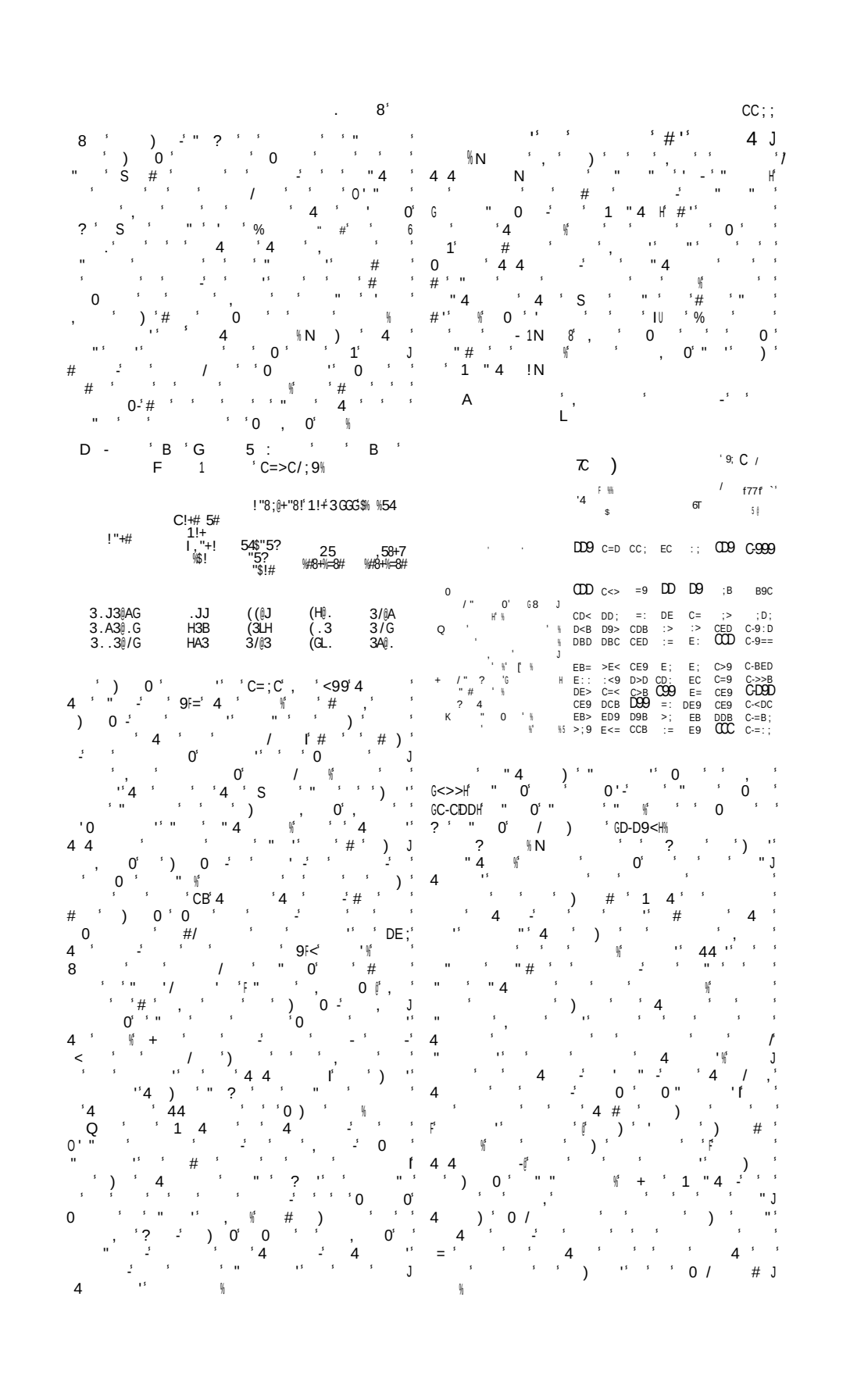

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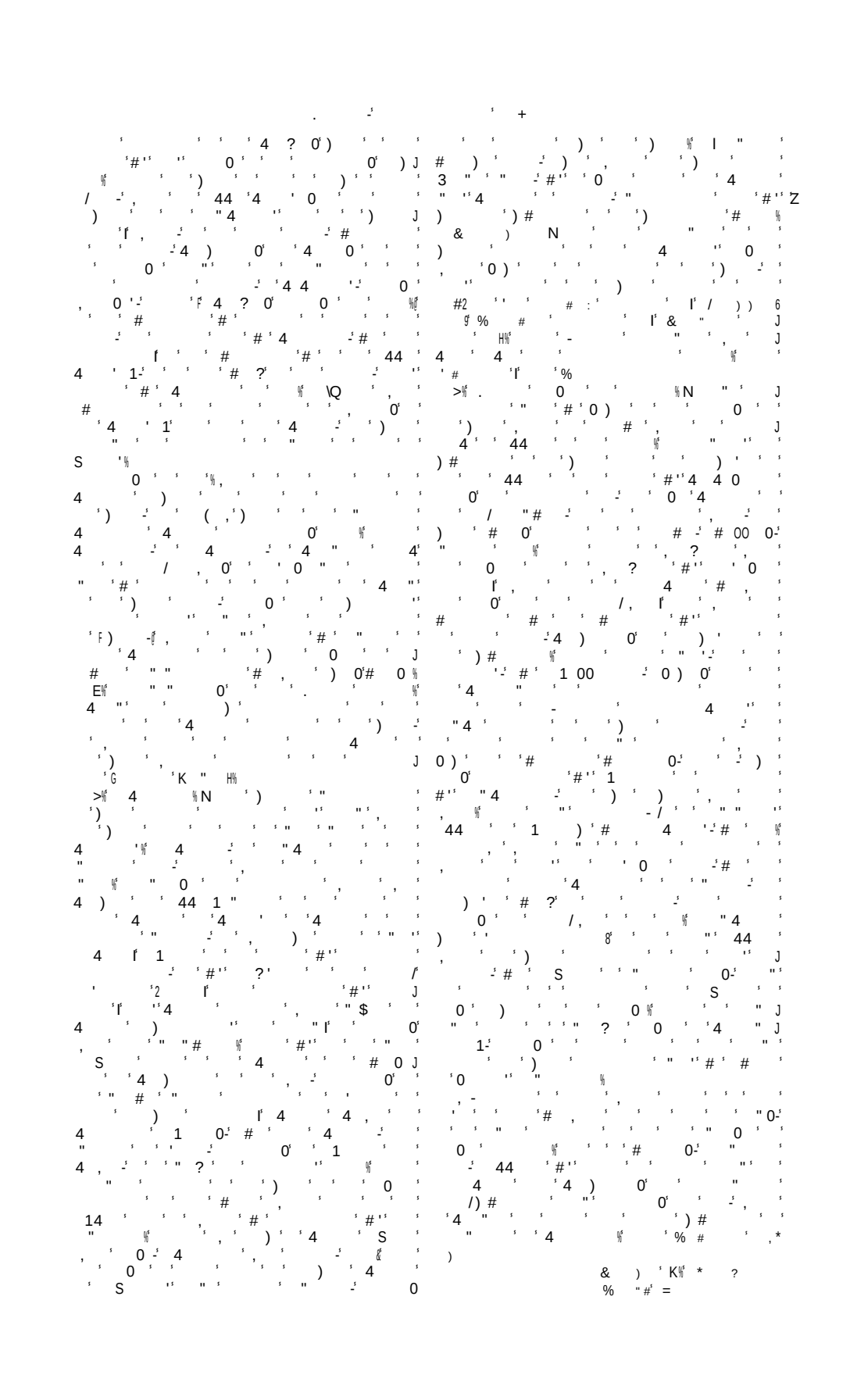

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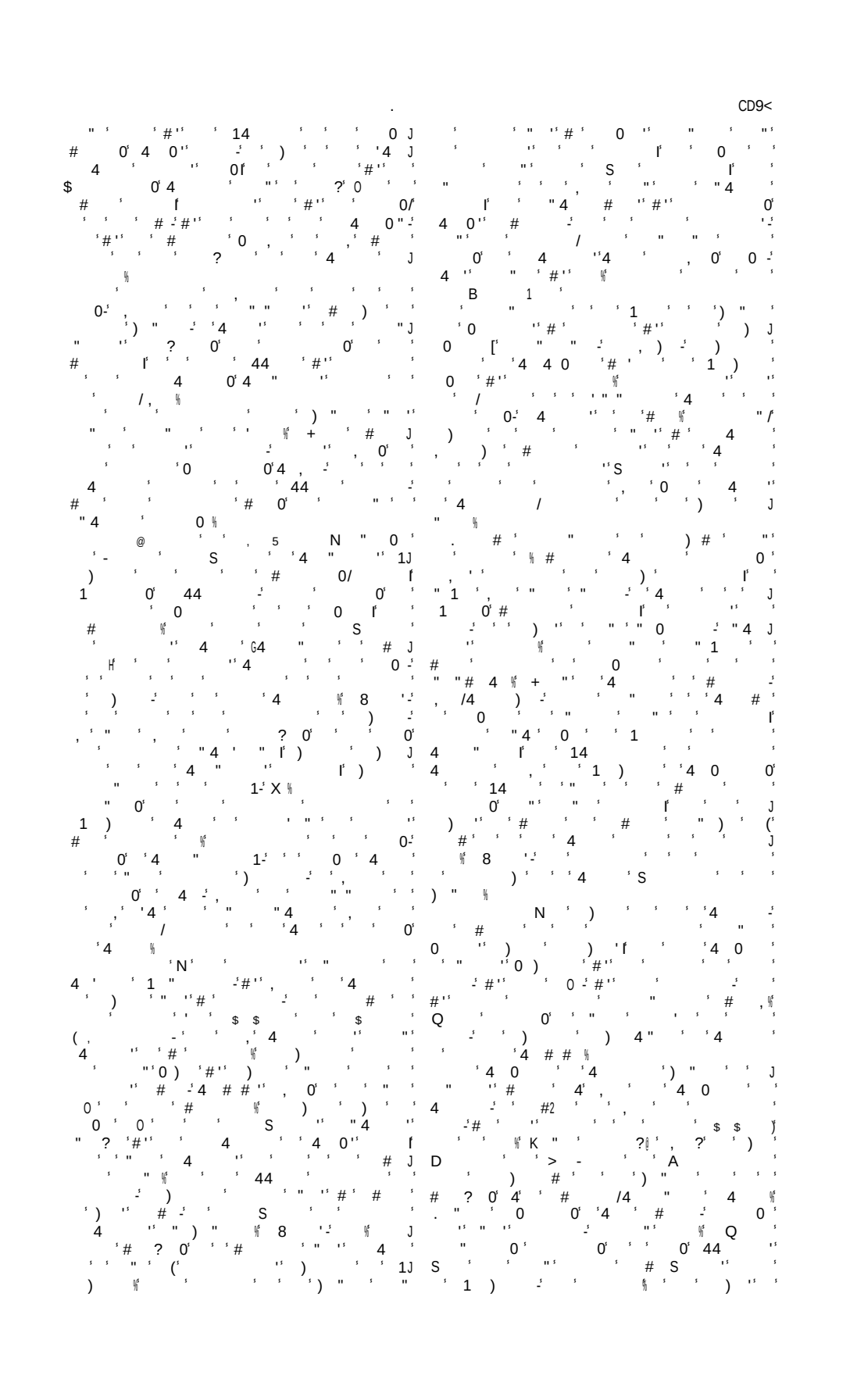

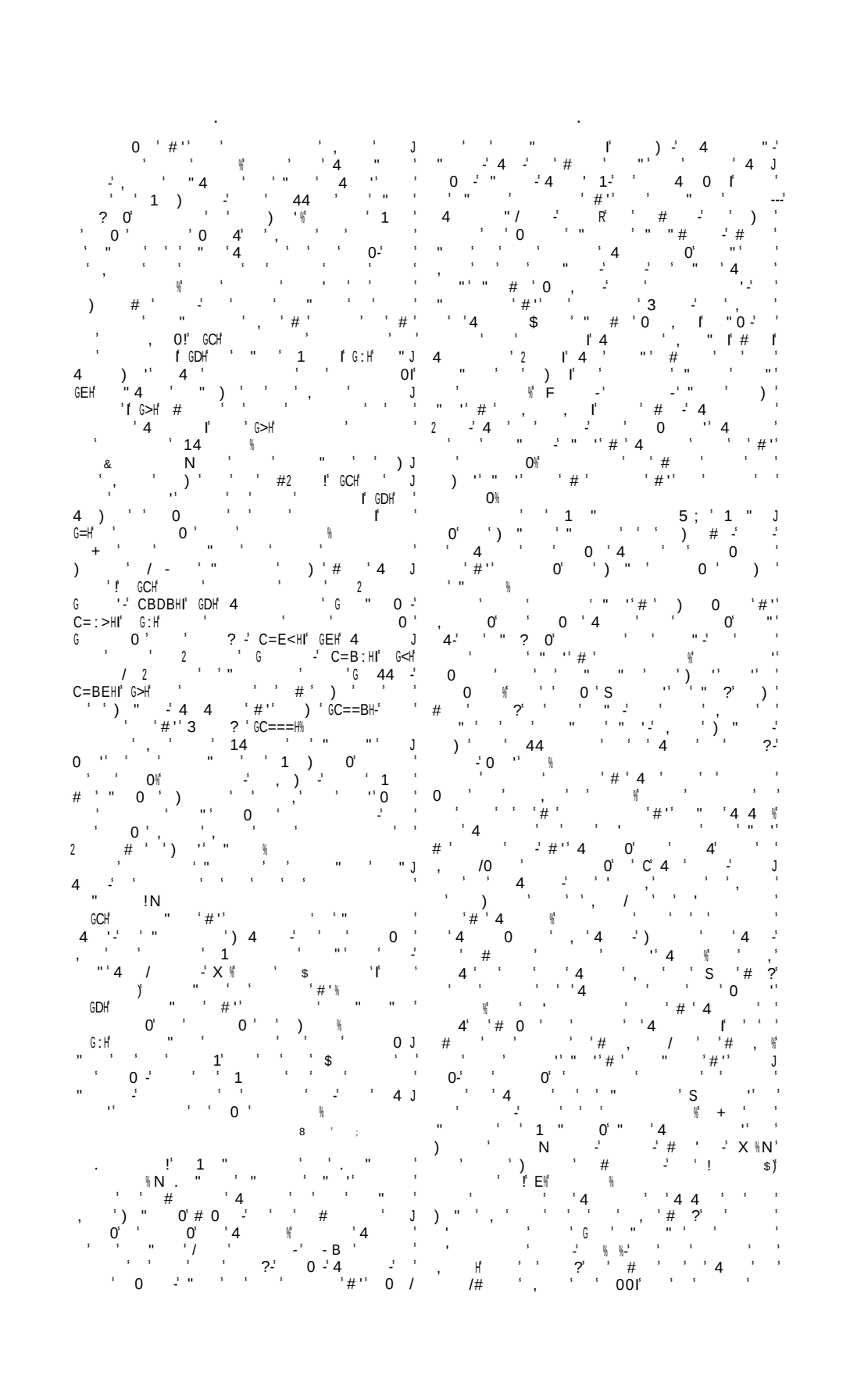

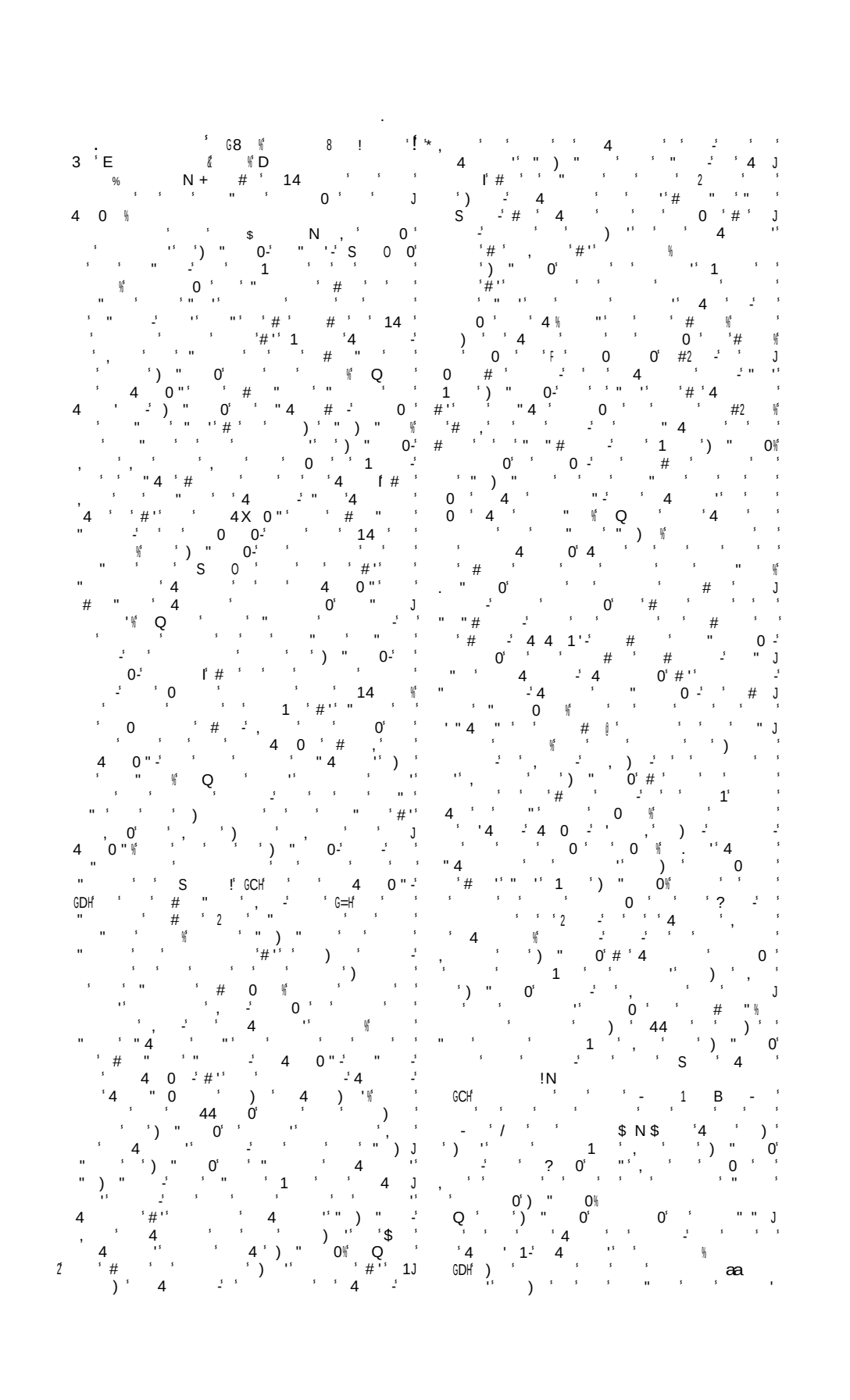

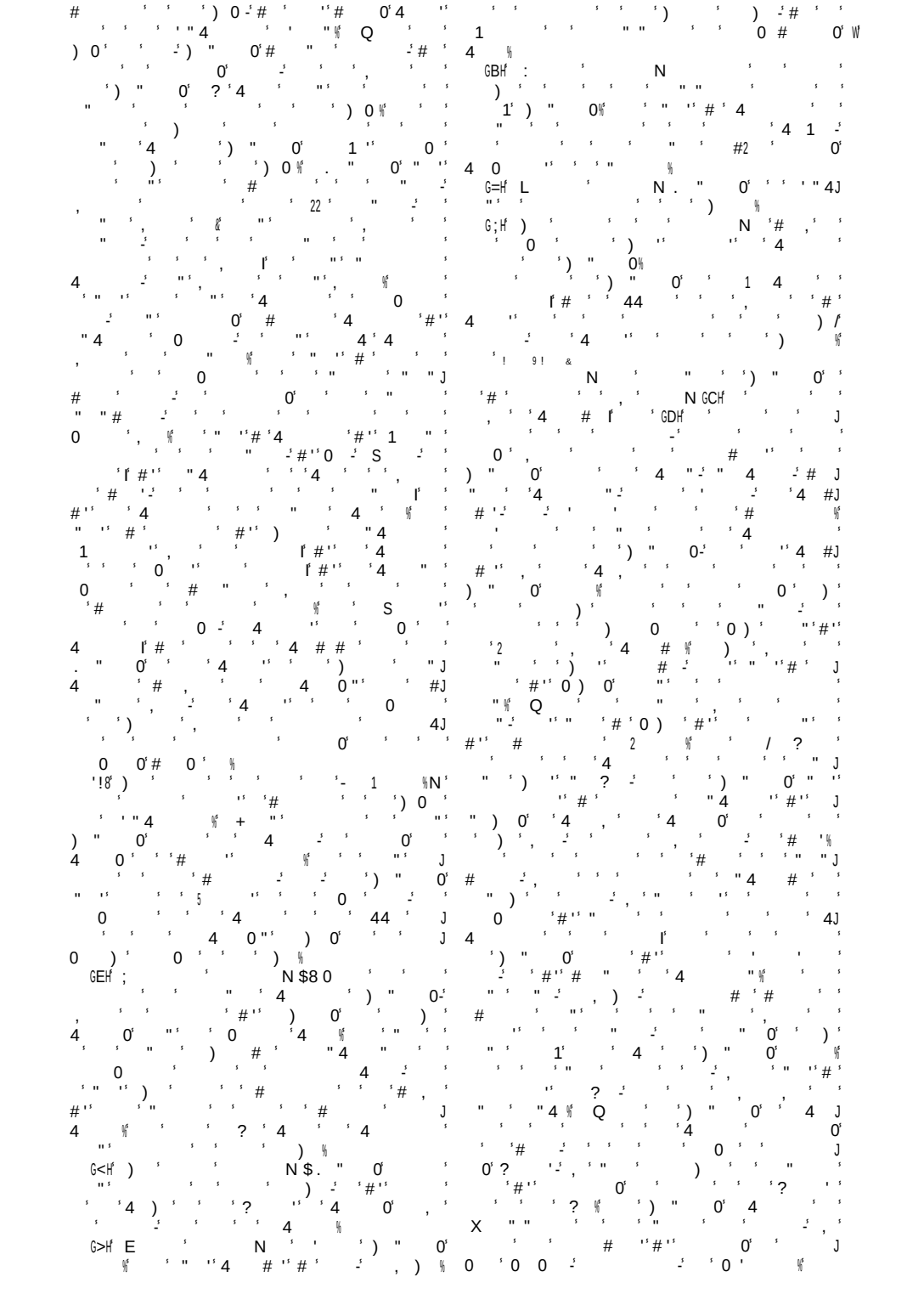

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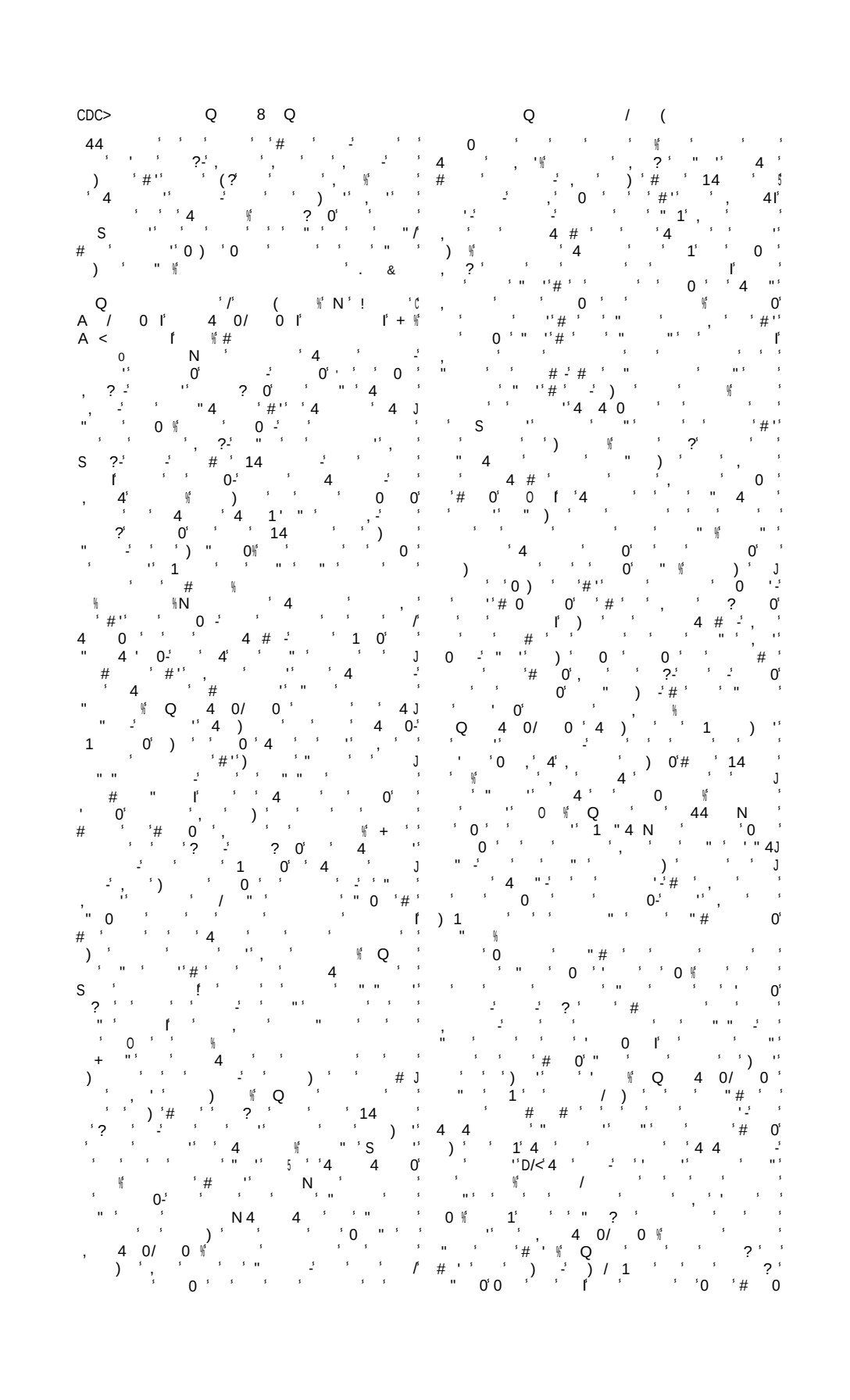

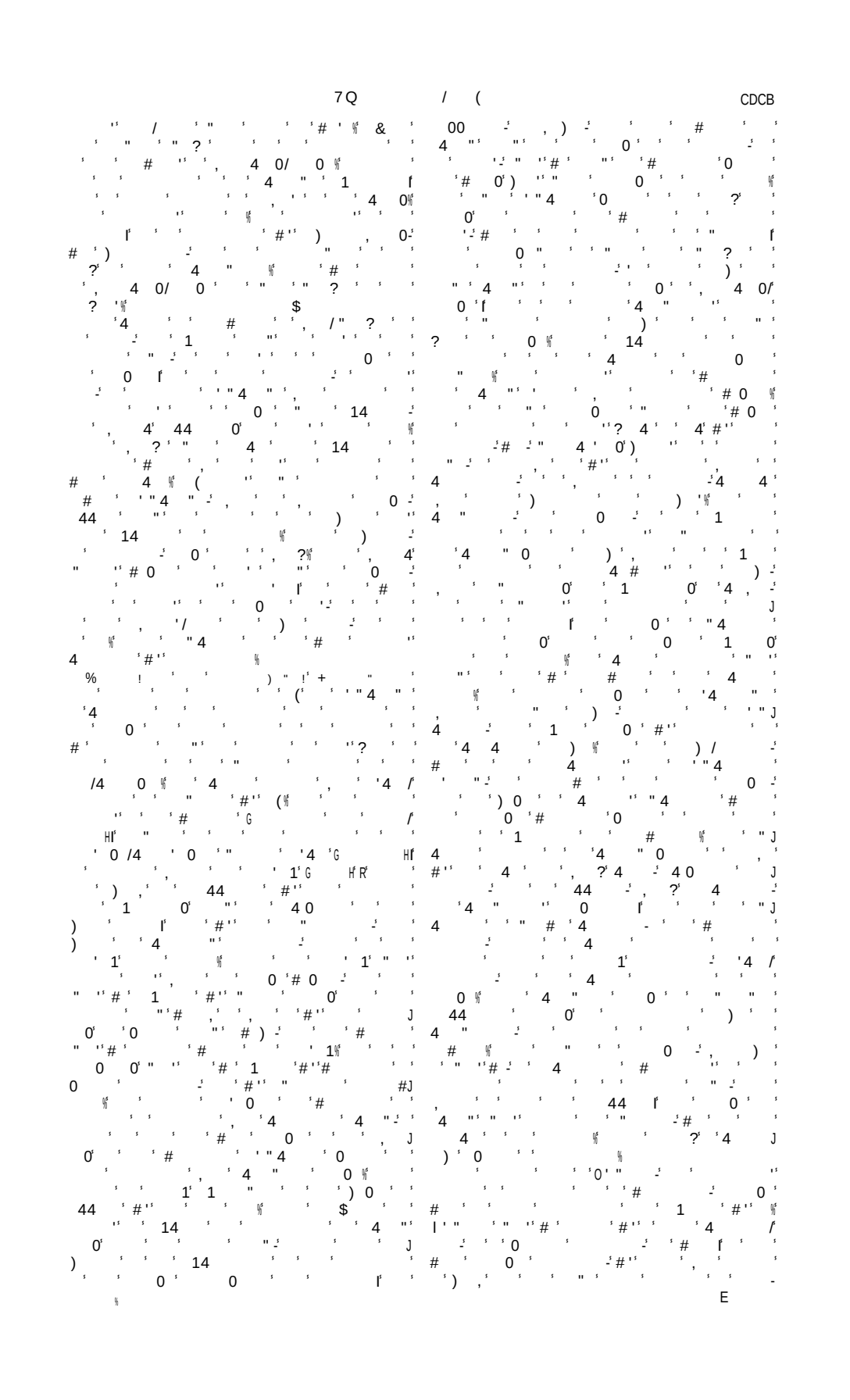

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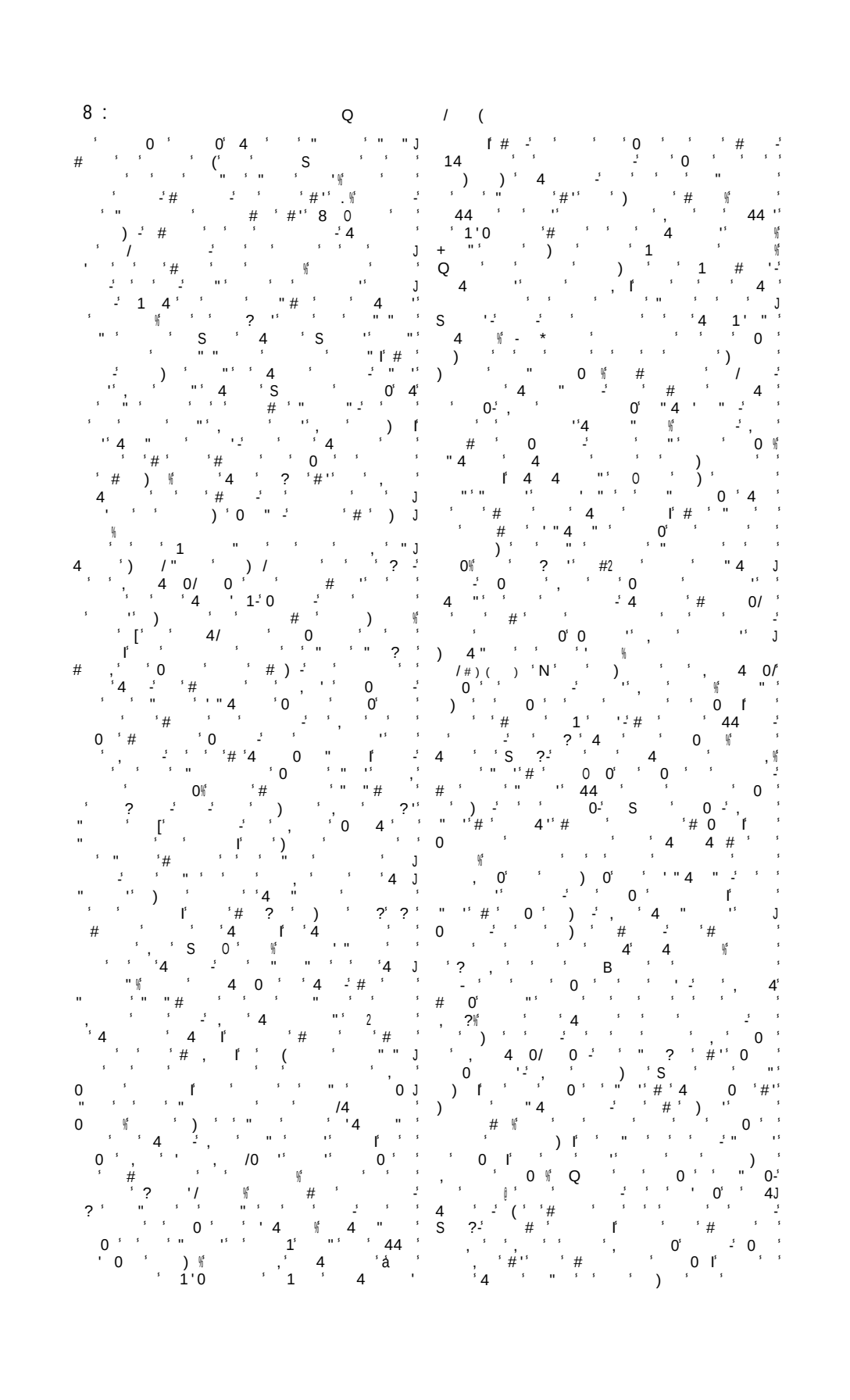

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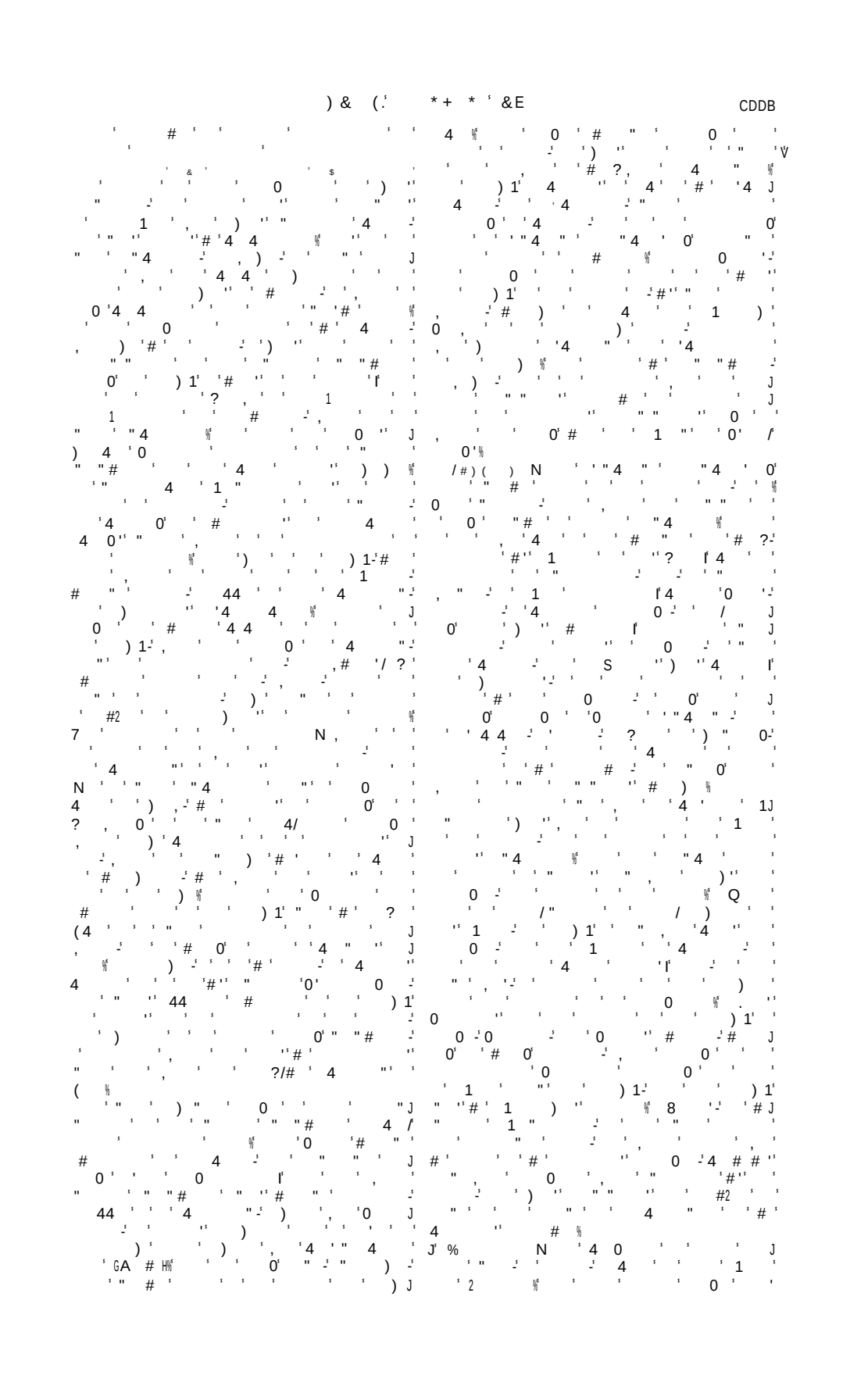
can also recognise any abnormal growth that exists about the cervix, as, for instance, small gelatinous polypi which have evaded the sense of touch.

4. *Examination with the Sound.* — In certain cases in which more accurate information regarding the state of the uterus is required, other accessory means of examination are used. One of these is the uterine sound (fig. 180), by means of which we can explore the interior of the uterus, measure its length, ascertain its direction, &c. The instrument is a thin rod of flexible metal, which can be bent into any desired shape, as it is sometimes necessary to adapt it to the altered curve of the uterine cavity. Its length is divided into inches by means of small notches in the metal, and at two and a-half inches from its point is a small knob, indicating the normal length of the healthy uterus. In introducing the sound, the index finger of the right hand is passed into the vagina until its tip rests on the opening of the os uteri, which can be felt as a dimple or depression at the extremity of the cervix. The handle of the sound being lightly held in the left hand, its point, previously warmed and oiled, is guided along the palmar surface of the index finger of the right hand, until it enters the os uteri. It is a good plan to pass the sound through the vagina with its concavity looking towards the perinæum, and after it has entered the os, to turn it gently round, so that its further progress may be in the ordinary direction of the uterine cavity. It is now gently pushed on, no force whatever being used, until its point is arrested by the fundus uteri. The tip of the right index finger is now placed at the os, and withdrawn in contact with the sound, so that the exact length to which it has entered may be ascertained. Considerable practice is required to pass the sound easily and without pain. Gentleness is necessary above all, and the sound should be coaxed to pass, being withdrawn if any resistance is met with, and never pushed on by force. Sometimes the sound will not pass in the ordinary direction, and then an endeavour must be made to adapt it to the curve of the uterine cavity, by bending it, or by passing it with its concavity backwards, as in the cases of retroflexion. The kind of information to be derived from the use of the sound will be best appreciated when treating of the separate diseases of the uterus.

FIG. 180.—The Uterine Sound.

5. *Dilatation of the Cervix.* — Another mode of examination, sometimes of much use, is the dilatation of the cervix by sponge or laminaria tents, or by Hegar's dilators, so as to admit of the introduction of a finger, and complete exploration of the uterine cavity. This is of immense service in cases of profuse menorrhagia, when the existence of an intra-uterine polypus, or portion of retained placenta, is suspected. The tent is a mass of compressed sponge, or a cylinder of laminaria digitata, sufficiently small to enter the cervix, where it swells by the imbibition of moisture, and in doing so expands the surrounding tissues. A good way of effecting the desired object is by passing side by side into the cervix a bundle of laminaria bougies, sufficiently long to reach the fundus. These, if left *in situ* for twenty-four hours, dilate not only the cervix but the whole uterine cavity, and admit of its being thoroughly explored under an anæsthetic. In order to effect this easily, the cervix should be exposed by a duck-bill speculum. Hegar's dilators are a series of graduated uterine bougies, made of vulcanite, one of which is inserted into the uterus for about two minutes, beginning with No. 1, and gradually progressing to No. 23 or 24. By this means comparatively rapid and very effective dilatation can be produced. Careful antiseptic precautions are essential, and the operation must be performed under an anæsthetic. In the hands of an expert this is probably the best method at our disposal. Dilatation of the cervix is an operation that should not be undertaken without due consideration, as it is occasionally followed by considerable irritation.

General Ætiology and Pathology of Uterine Disease.—Much as is the attention which has been paid to uterine disease of late years, the opinions of the profession are as yet far from being decided on many elementary facts connected with it. It is beyond doubt that in this class of disease there are a series of symptoms common to all cases alike, such as pain in the lower part of the abdomen and back, inability to walk, leucorrhœal discharge, and disordered menstruation. If, however, modern writers on gynæcology are consulted, it will be at once seen how various and irreconcilable are the explanations given of these symptoms. Thus we have a school who teach that in inflammation and congestion, either of the cervix alone, or of the body or lining membrane of the uterus, we have the key to uterine pathology, and that all other changes detected in the uterus, such as displacements or flexions, are merely secondary results of the primary affection. On the other hand, there are many influential gynæcologists who refer all uterine disease to mechanical causes; who consider



the mucous membrane at any part of the uterine cavity, and apply our remedies to it, without the necessity of any preliminary dilatation. The probes used by the writer are made of flexible metal (fig. 181), attached to a wooden handle, and of such a size that, when tightly wrapped round with a thin film of wool, they are not thicker than an ordinary uterine sound. They are covered by teasing out a small portion of wool, which is flattened between the palms of the hands. The probe is then dipped in water, to cause the wool to adhere, and by twisting round the handle, the wool being held between the forefinger and thumb of the left hand, the wool is smoothly and firmly wrapped round it. A little practice enables us to effect this with great neatness. The cervix being generally abnormally patulous, there is no difficulty in passing the probes through the os, previously exposed by the speculum, so as to reach the entire uterine cavity. The writer is in the habit of using a mixture of equal parts of crystallised carbolic acid and glycerine, as a local alterative, than which, he believes, there is no better application. Others, however, employ tincture of iodine, or strong solutions of nitrate of silver; or they even, as recommended by Courty of Montpellier, pass a solid piece of nitrate of silver into the uterine cavity, leaving it there to melt and flow over the mucous membrane. The writer first swabs out the uterine cavity with one or two probes covered with dry wool, so as to remove the glutinous discharge as much as possible, and then passes in another probe, covered with the carbolic solution, so as to paint over the lining membrane of the cervix and body of the uterus, the external abrasions on the cervix being subsequently swabbed over with the same solution. This rarely gives rise to any pain or discomfort, and may be combined with the other plans of treatment already mentioned. Intra-uterine medication is most useful in the week immediately succeeding menstruation, when the superficial layer of the mucous membrane has been shed. If used too near the advent of the next period it may prove too irritating, and may bring on menstruation prematurely. As a rule, two applications, at intervals of a few days, in the early part of the intra-menstrual interval are amply sufficient, and it may be necessary to continue the treatment for many weeks or months. The writer of late has found the application of the continuous electrical current, through a carefully insulated sound, a still more efficient and much more rapidly effectual method of intra-uterine medication. Some three or four applications of about 100 milliampères will often effectually cure an intra-uterine leucorrhœa of long persistence. Unfortunately this is a method of treatment that is not generally applicable, since it requires an expensive plant, and very considerable practical experience, in order that it may be safely and efficiently used. Should laceration of the cervix and ectropion exist, Emmett's operation of trachelorrhaphy may be indicated. In very severe and obstinate cases of this kind Recamier used to scrape the uterine mucous membrane with a curette, so as to remove the granulations, especially when there was much metrorrhagia, and where there was reason to suspect the existence of a granular condition of the intra-uterine mucous membrane. The Dublin physicians recommend the application of fuming nitric acid, the cervix having been first dilated with tents. This is a very strong measure, which we would not willingly adopt; but it is only fair to say that in the cases in which the writer has used it he has found it exceedingly useful. Scraping the uterine cavity with the dull wire curette also occasionally has an admirable result in such conditions; and, so far as the writer's experience goes, this is a perfectly safe procedure. Before concluding this subject, a word of caution is necessary. Valuable as intra-uterine medication certainly is in suitable cases, it should never be rashly or indiscriminately employed, and the writer would strongly insist that, before resorting to it, we should satisfy ourselves that the uterus is likely to bear it with impunity. Whenever, therefore, there is much tenderness of the womb on being touched, even when the case is otherwise suitable, the writer deems it advisable first to remove the congested condition by rest, the local abstraction of blood, the use of glycerine pledgets, hot-water irrigations, and other appropriate means; and, above all, the slightest evidence of any concomitant mischief or irritation, recent or of old standing, in the neighbourhood of the uterus, as shown by tenderness on pressure in the region of the broad ligaments, or fixity of the uterus, should be an absolute contra-indication.

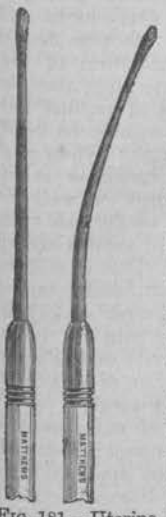
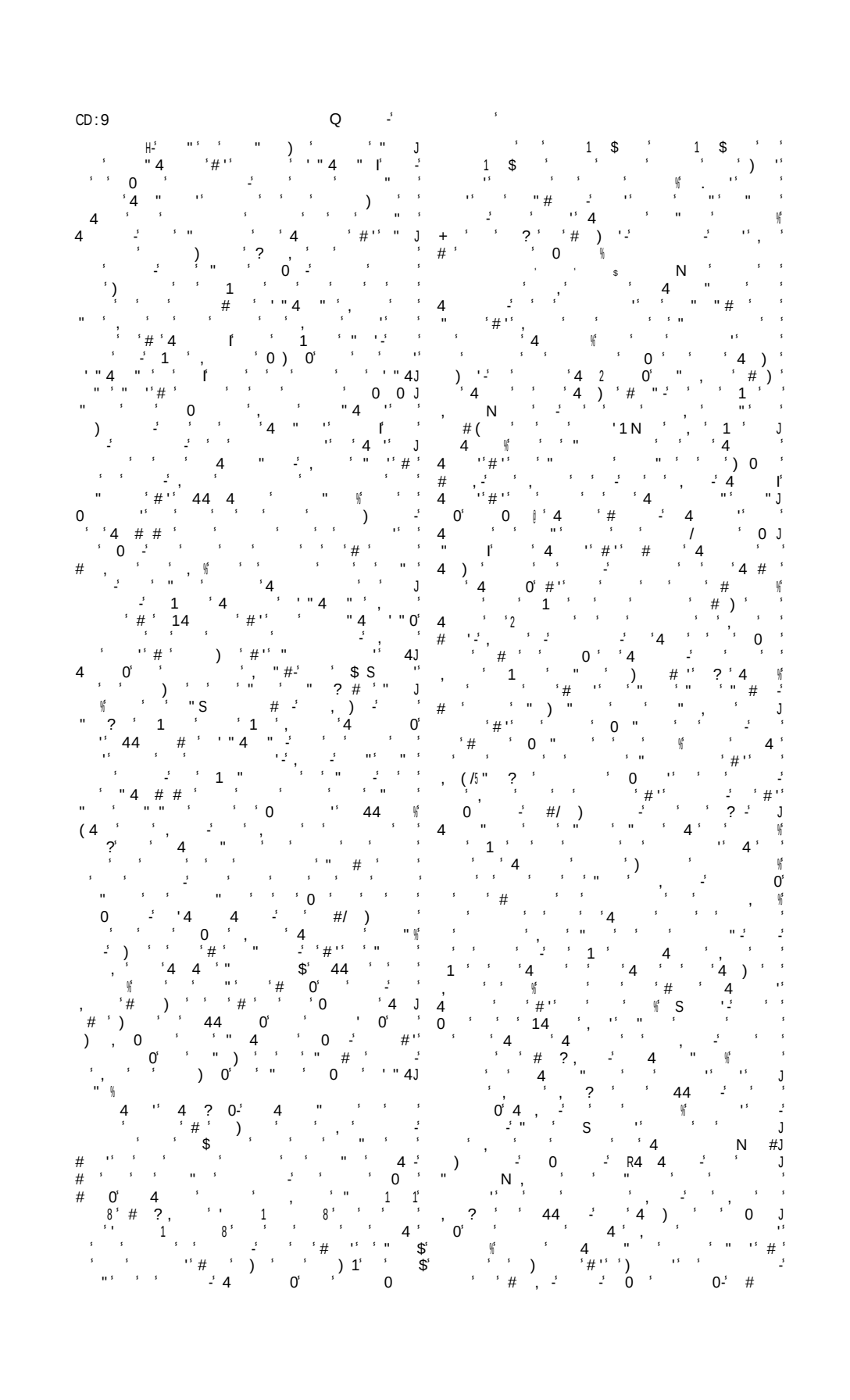


FIG. 181.—Uterine Probes.

2. **Displacements.**—Under this head we have to discuss a variety of diseases which have furnished a fruitful theme for controversy among gynæcologists. Practically, physicians have divided themselves into two great schools with regard to these affections. One of these schools teaches that deviations of the uterus, in whatever direction they occur, whether forwards, backwards, or to either side (for descent of the uterus is of a different character, and must be separately



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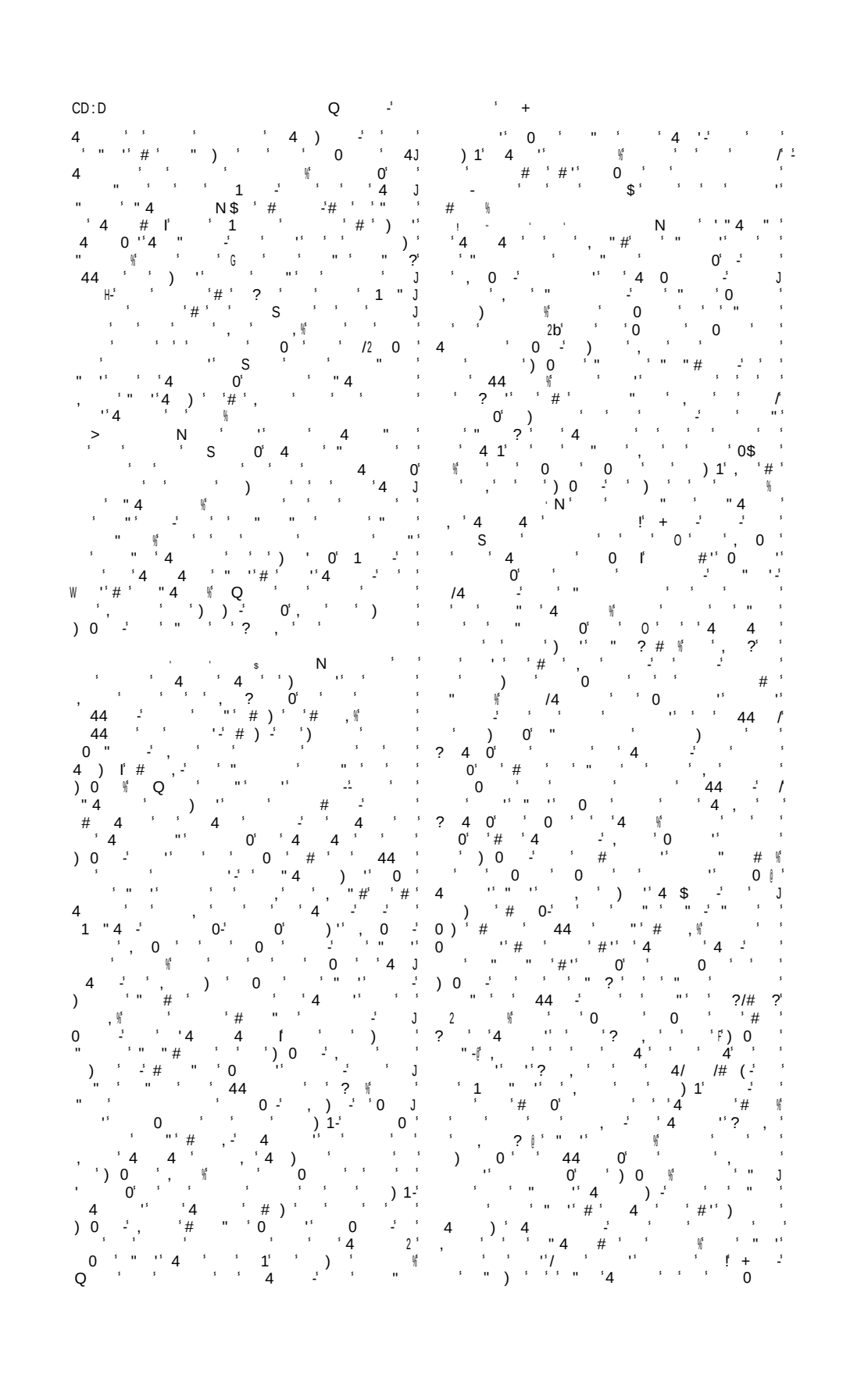

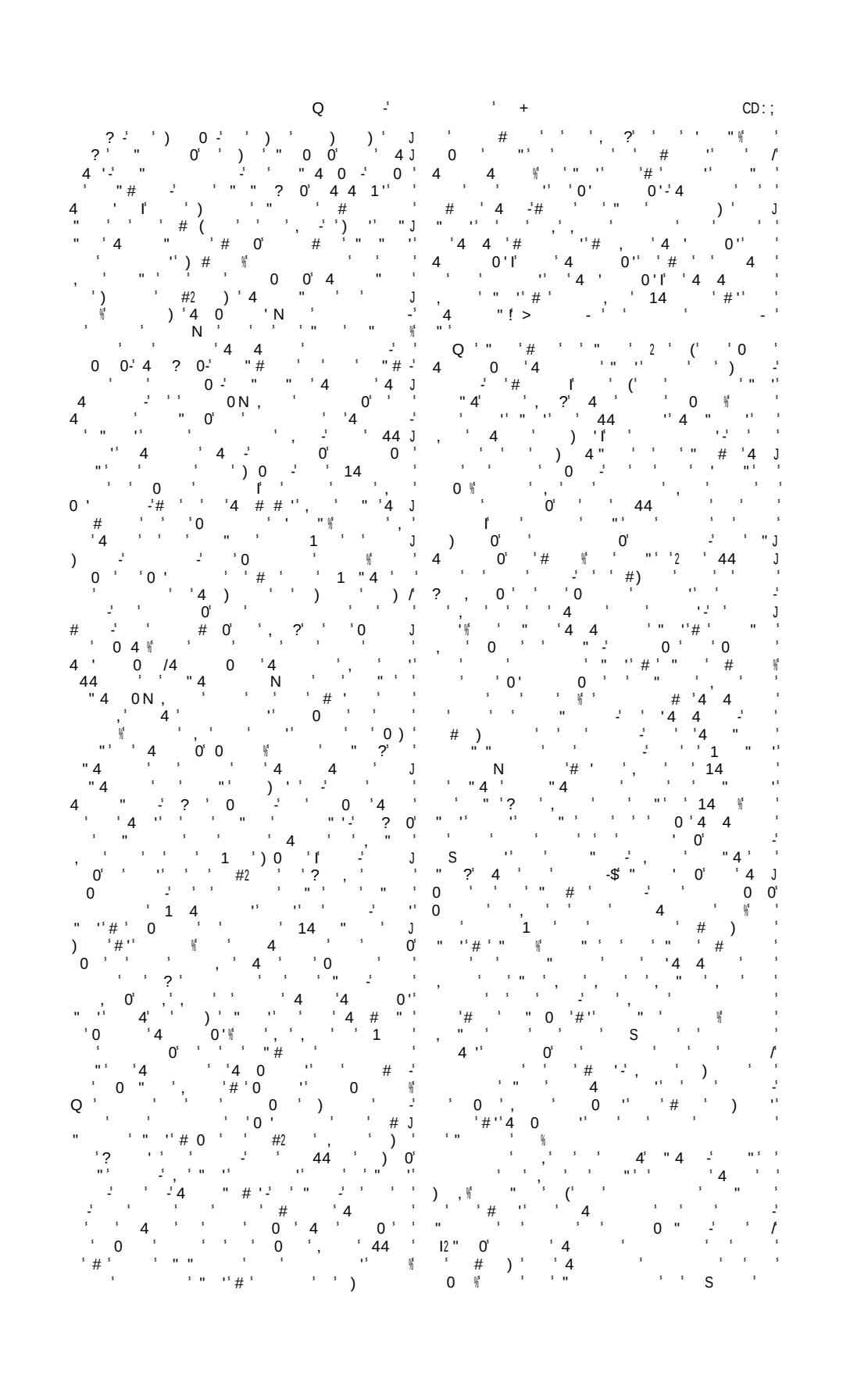

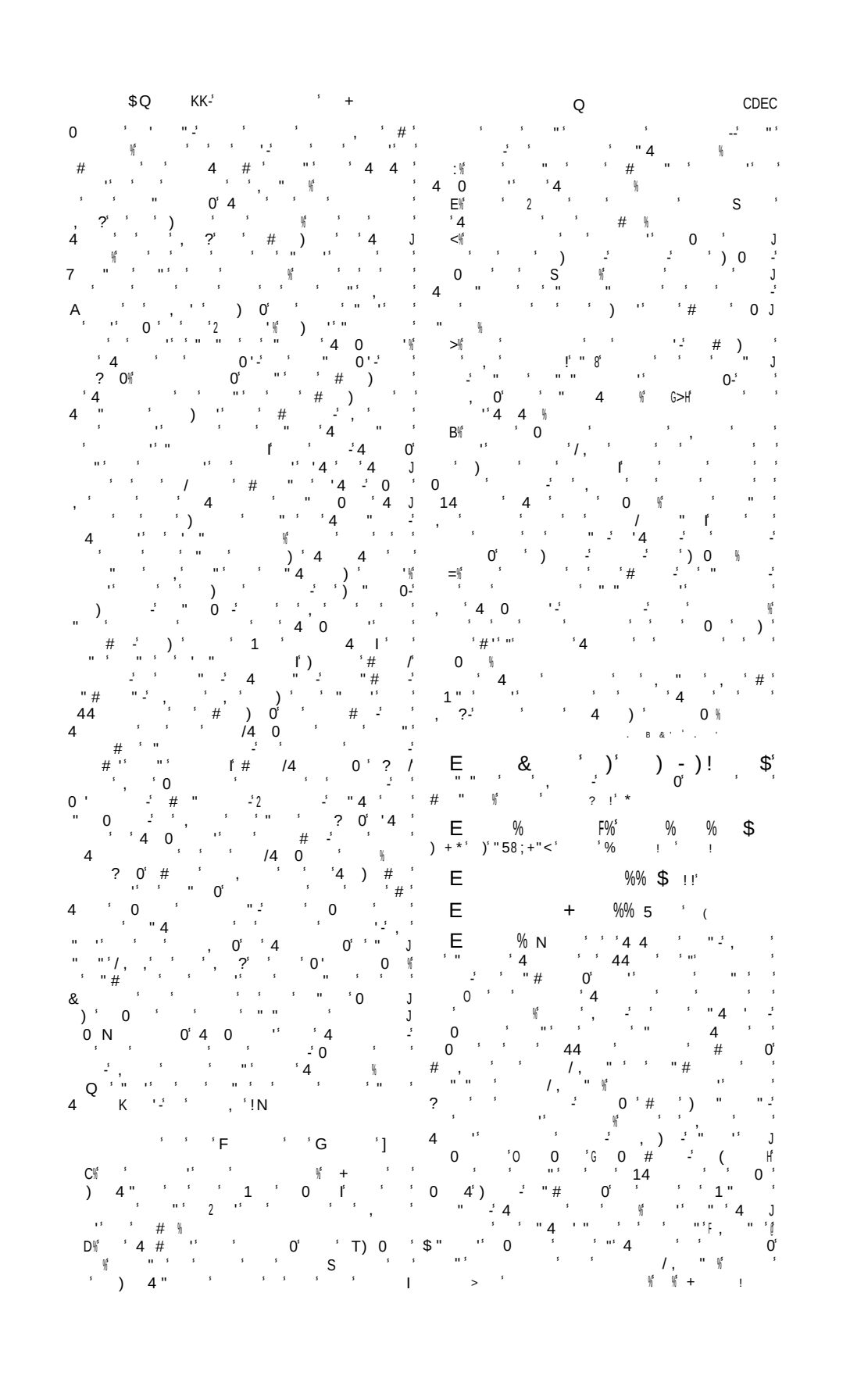

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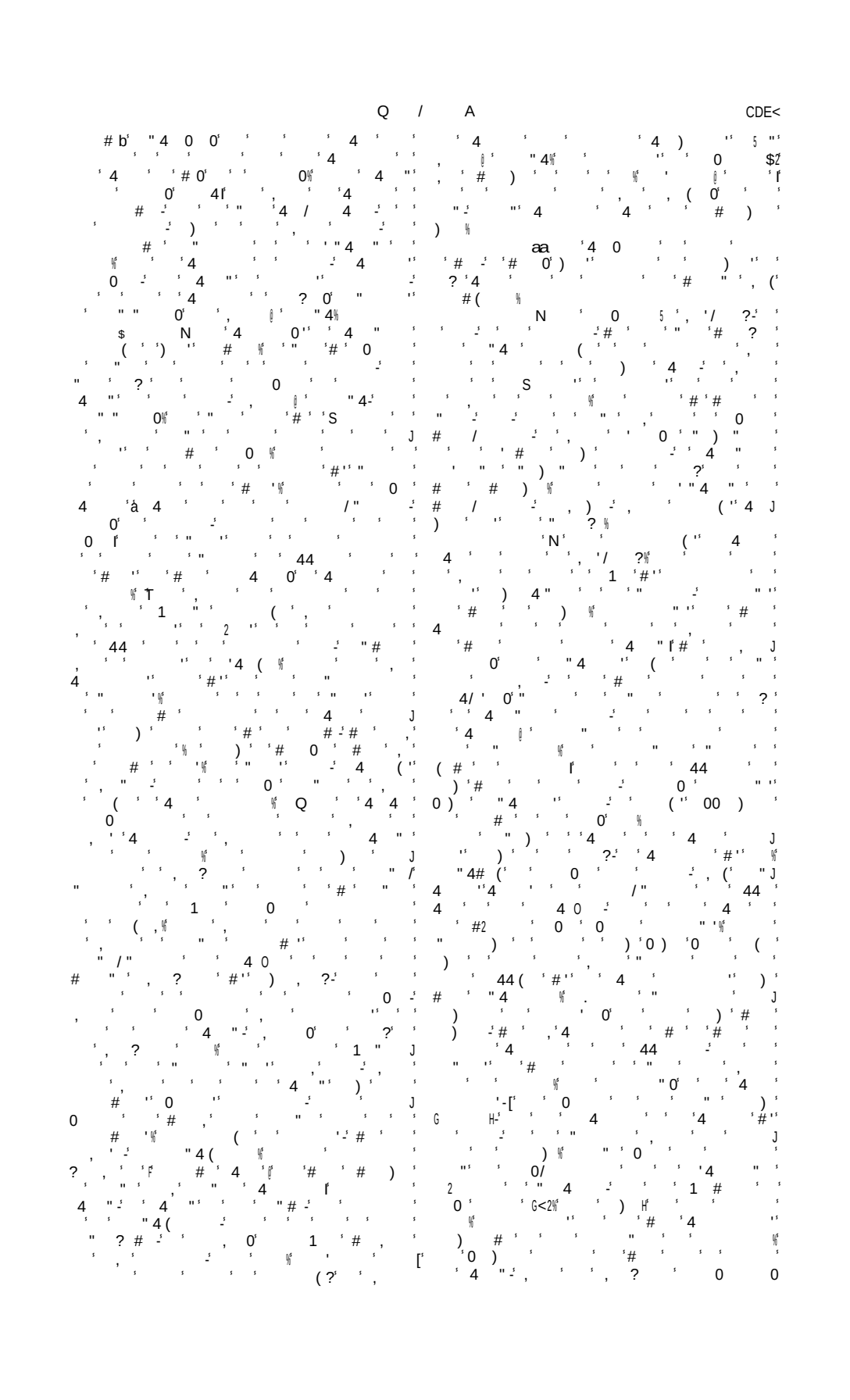

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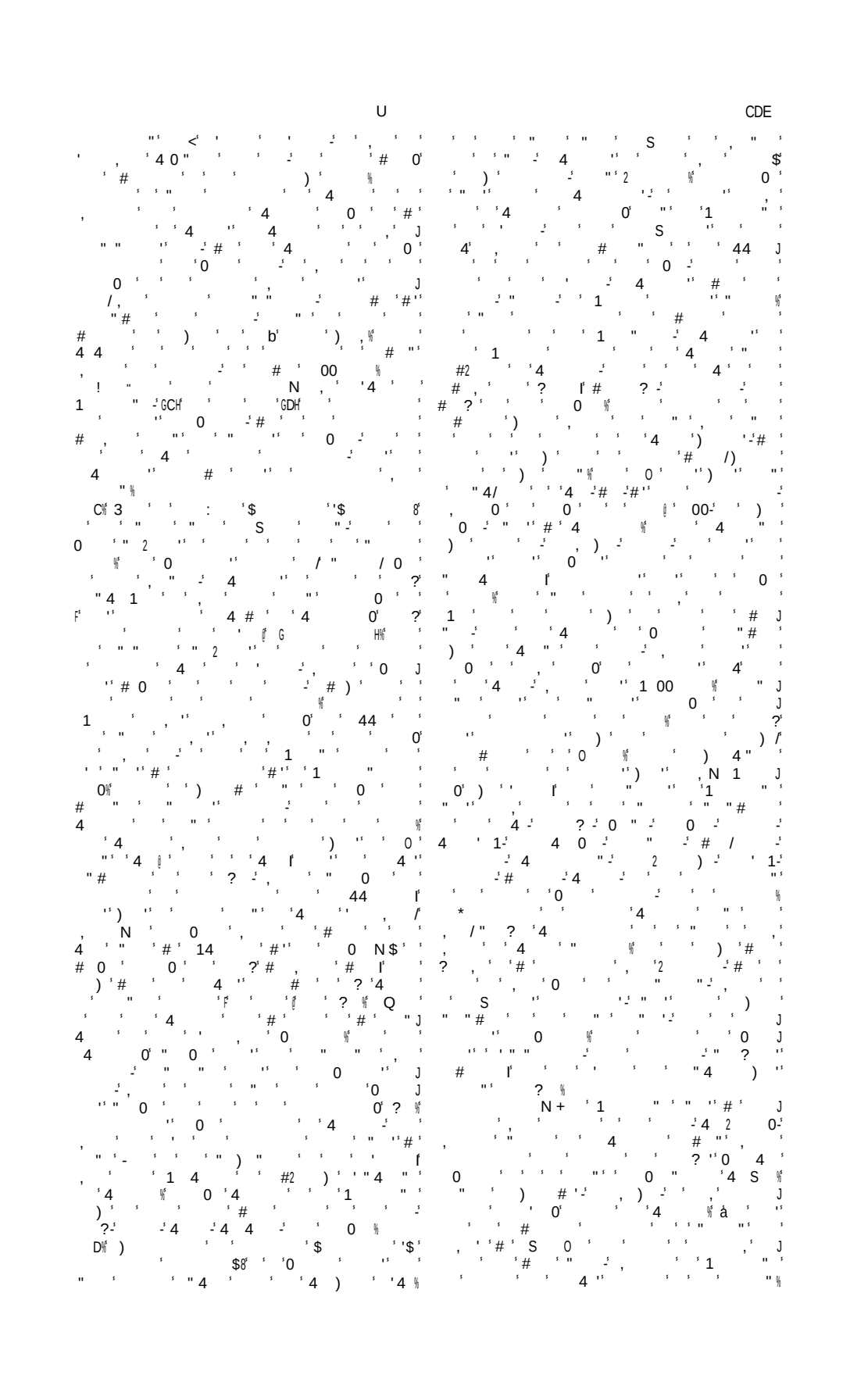

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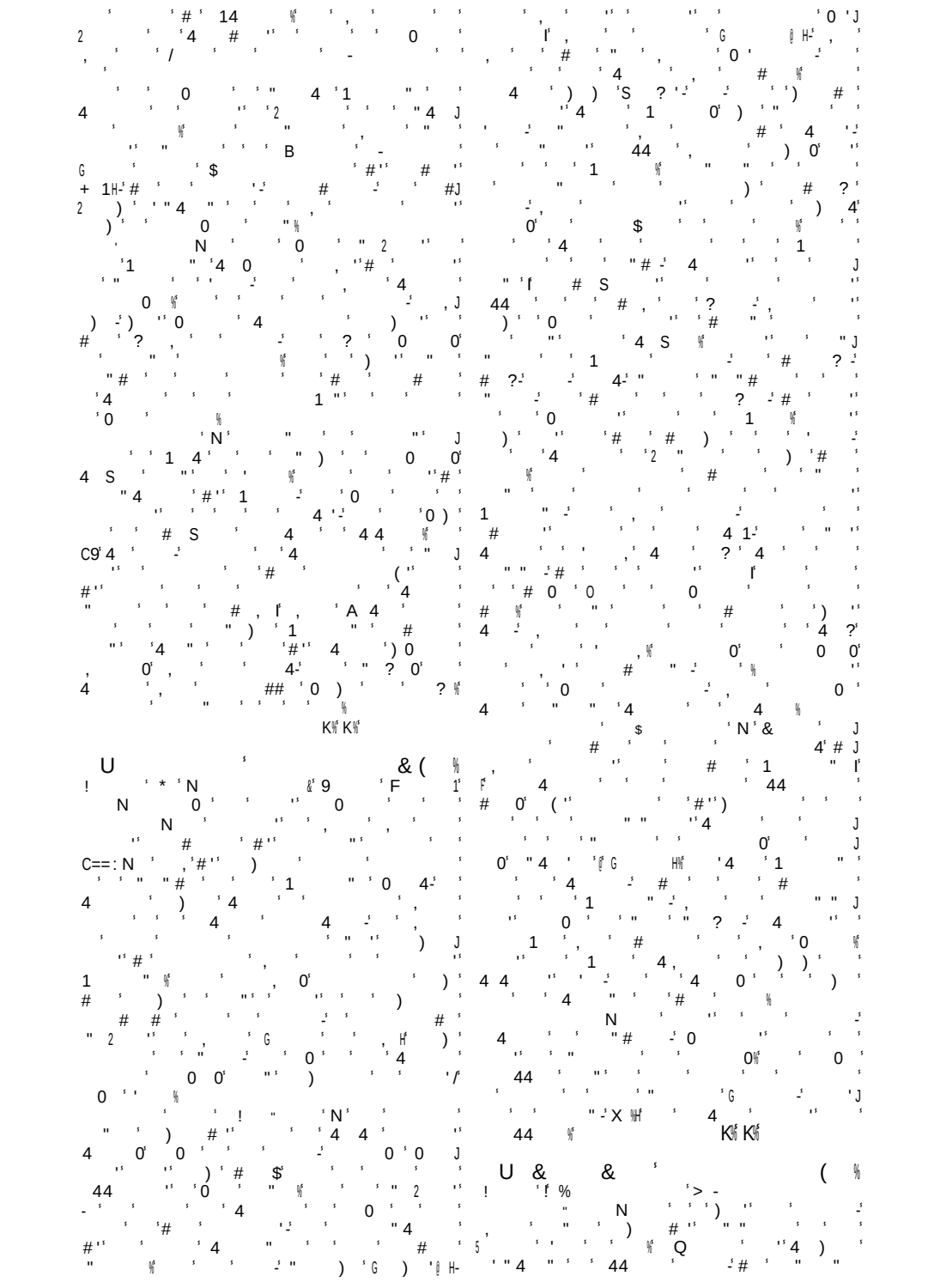

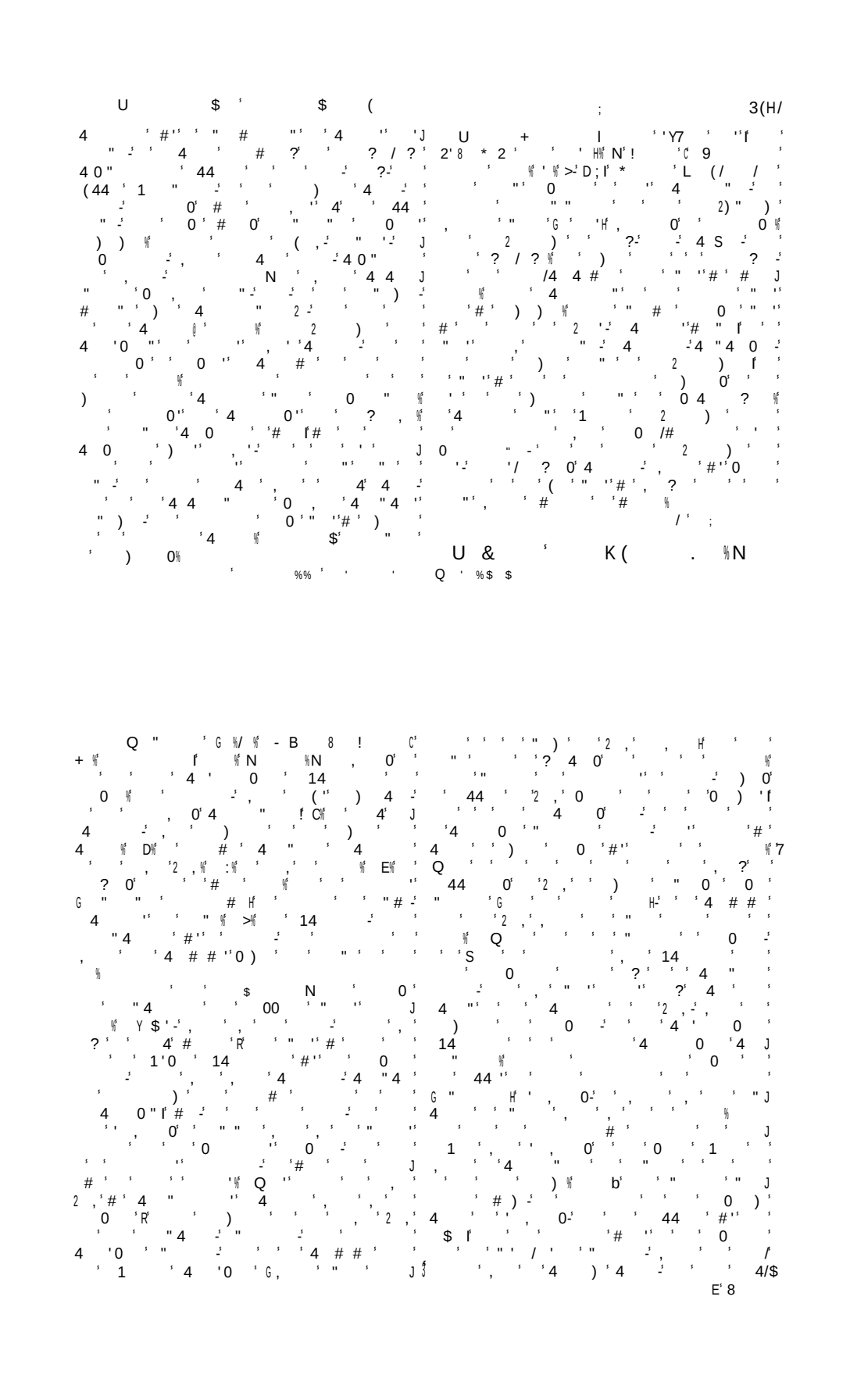

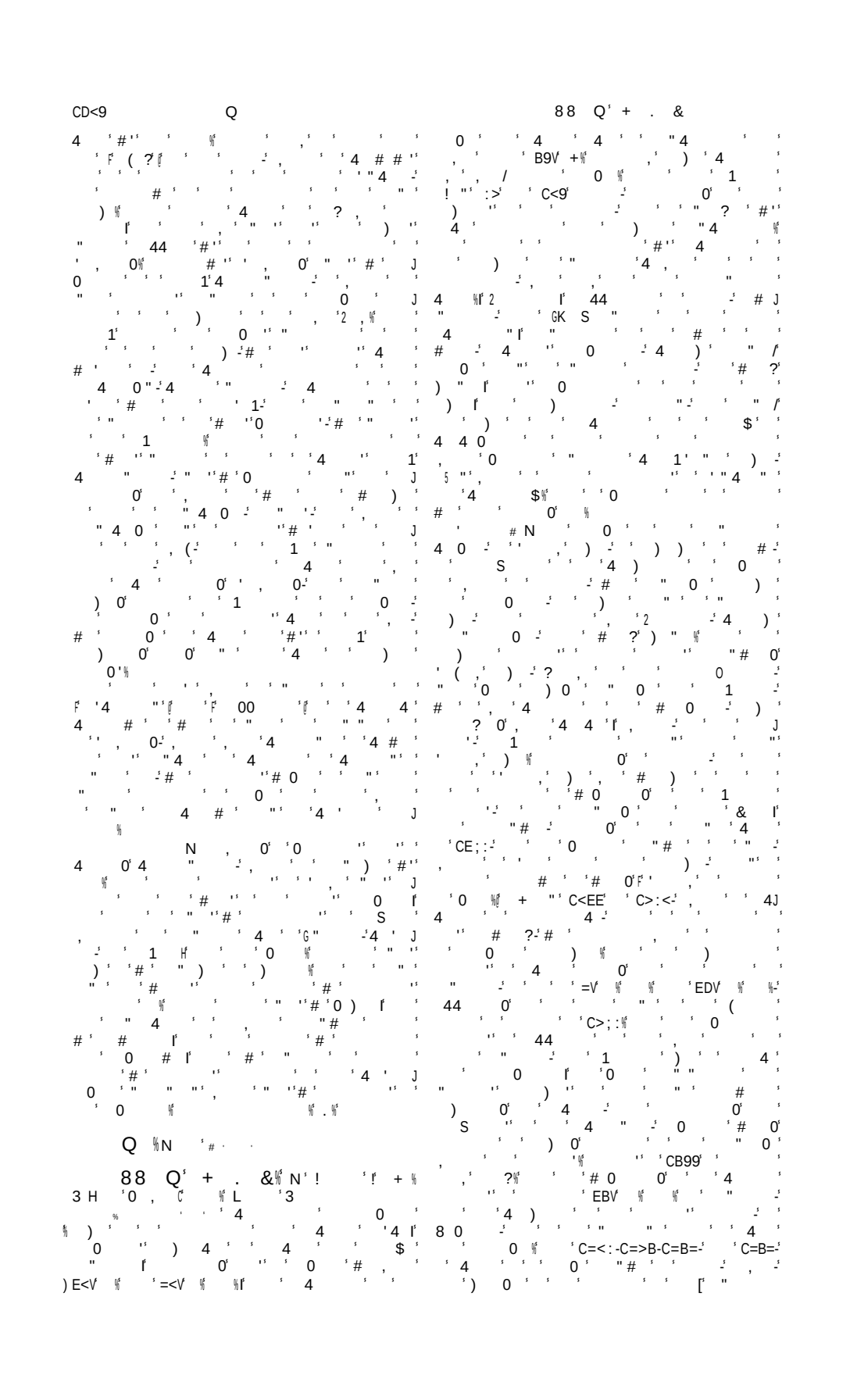

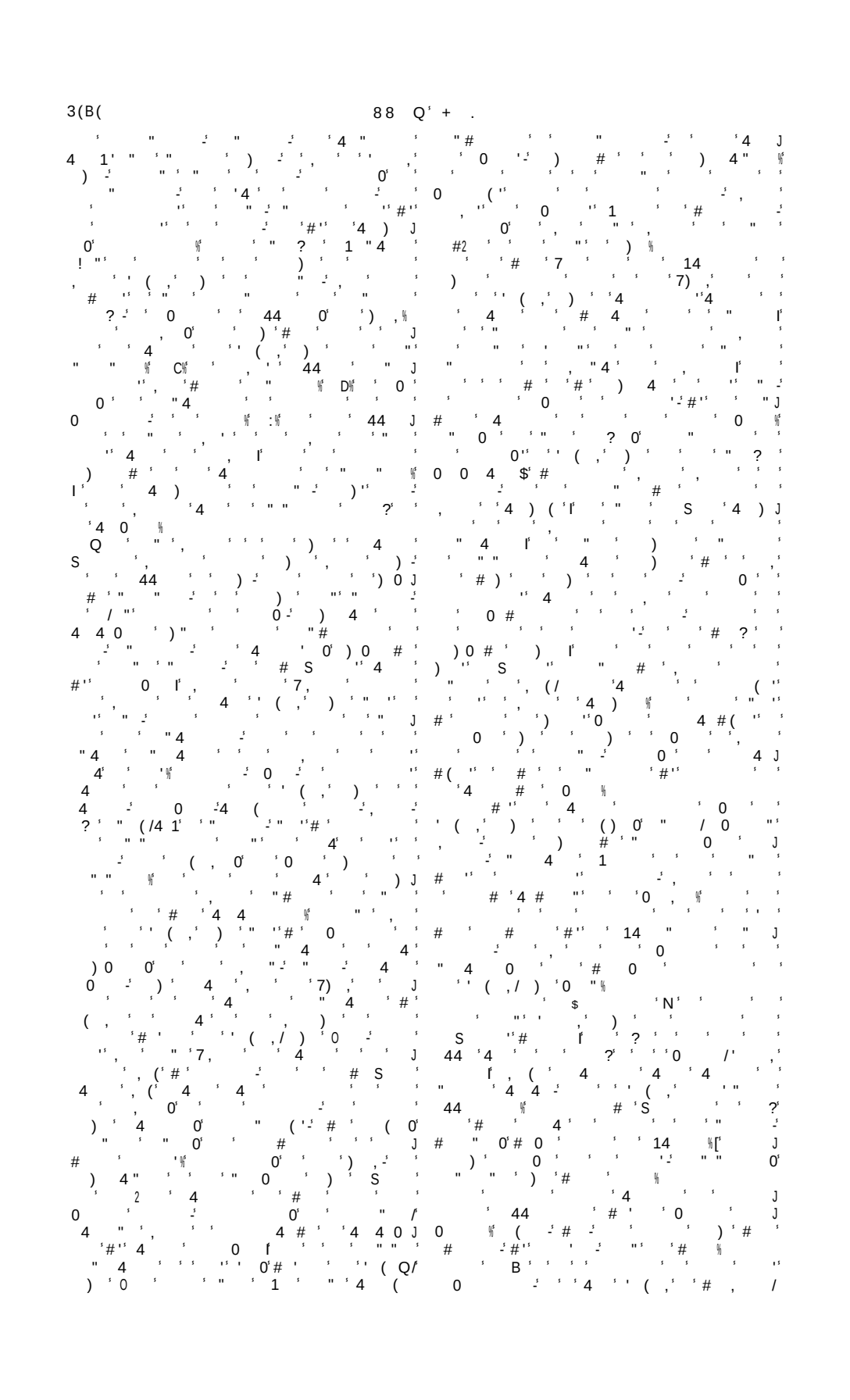

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